This is a digital copy of a book that was preserved for generations on library shelves before it was carefully scanned by Google as part of a project to make the world's books discoverable online.

It has survived long enough for the copyright to expire and the book to enter the public domain. A public domain book is one that was never subject to copyright or whose legal copyright term has expired. Whether a book is in the public domain may vary country to country. Public domain books are our gateways to the past, representing a wealth of history, culture and knowledge that's often difficult to discover.

Marks, notations and other marginalia present in the original volume will appear in this file - a reminder of this book's long journey from the publisher to a library and finally to you.

Usage guidelines

Google is proud to partner with libraries to digitize public domain materials and make them widely accessible. Public domain books belong to the public and we are merely their custodians. Nevertheless, this work is expensive, so in order to keep providing this resource, we have taken steps to prevent abuse by commercial parties, including placing technical restrictions on automated querying.

We also ask that you:

+ *Make non-commercial use of the files* We designed Google Book Search for use by individuals, and we request that you use these files for personal, non-commercial purposes.

+ *Refrain from automated querying* Do not send automated queries of any sort to Google's system: If you are conducting research on machine translation, optical character recognition or other areas where access to a large amount of text is helpful, please contact us. We encourage the use of public domain materials for these purposes and may be able to help.

+ *Maintain attribution* The Google "watermark" you see on each file is essential for informing people about this project and helping them find additional materials through Google Book Search. Please do not remove it.

+ *Keep it legal* Whatever your use, remember that you are responsible for ensuring that what you are doing is legal. Do not assume that just because we believe a book is in the public domain for users in the United States, that the work is also in the public domain for users in other countries. Whether a book is still in copyright varies from country to country, and we can't offer guidance on whether any specific use of any specific book is allowed. Please do not assume that a book's appearance in Google Book Search means it can be used in any manner anywhere in the world. Copyright infringement liability can be quite severe.

About Google Book Search

Google's mission is to organize the world's information and to make it universally accessible and useful. Google Book Search helps readers discover the world's books while helping authors and publishers reach new audiences. You can search through the full text of this book on the web at `http://books.google.com/`

ENGINEER DEPARTMENT, UNITED STATES ARMY.

REPORTS ON THE CONSTRUCTION
OF
THE PIERS OF THE AQUEDUCT
OF
THE ALEXANDRIA CANAL
ACROSS
THE POTOMAC RIVER AT GEORGETOWN, DISTRICT OF COLUMBIA

BY

WILLIAM TURNBULL,
MAJOR CORPS TOPOGRAPHICAL ENGINEERS, UNITED STATES ARMY.

1835—1840.

WASHINGTON:
GOVERNMENT PRINTING OFFICE.
1873.

LETTER OF THE CHIEF OF ENGINEERS.

OFFICE OF THE CHIEF OF ENGINEERS,
Washington, D. C., December 31, 1872.

SIR: The reports of the progress of the construction of the piers of the aqueduct of the Alexandria Canal across the Potomac, at Georgetown, made from time to time to the Chief of the Corps of Topographical Engineers by the engineer in charge, Major Turnbull, were printed by Congress in 1838 and 1841, with accompanying drawings. They have been called for on several occasions by persons engaged in similar undertakings; but there are no copies remaining on the files of this Office for distribution. They are of special interest to the engineer on account of the unusual depth of foundations and the difficulties encountered in establishing them.

I would suggest the propriety of reprinting, by the Public Printer, such portions of these reports as are of special interest for the use of the Corps of Engineers.

Very respectfully, your obedient servant,

A. A. HUMPHREYS,
Brigadier-General and Chief of Engineers.

Hon. W. W. BELKNAP,
Secretary of War.

Approved by the Secretary of War.
JANUARY 3, 1873.

POTOMAC AQUEDUCT.

REPORT ON THE CONSTRUCTION OF THE POTOMAC AQUEDUCT, BY WILLIAM TURNBULL, MAJOR UNITED STATES TOPOGRAPHICAL ENGINEERS.

Potomac Aqueduct, *January* 1, 1836.

Sir: I have the honor to report that, immediately on the receipt of your order of the 29th of August, 1832, concerning the Potomac aqueduct, I communicated the same to T. F. Mason, esq., the president of the Alexandria Canal Company; and I soon after made the necessary examinations to enable me to determine the proper position of, the extent, character, and cost of the work. By these surveys were ascertained the depth of the river from the plane of high water to the muddy bottom, and the depth and nature of the deposit beneath the river to the solid rock which underlies it; the direction and probable velocities of the curent, and the length and direction of the aqueduct, and of its abutments and embankments; the quantity of excavation necessary to carry the masonry to a solid foundation, and the strength which should be given to the structure to enable it to resist the pressure of the ice and other floating matter which is carried down by the freshets of the river.

The site of the aqueduct had been already fixed, in 1829, by Messrs. Wright and Roberts, engineers of the Chesapeake and Ohio Canal Company, as may be seen by their report of that year. Among the drawings which accompany their report there is one which would seem to be a profile of the river, and to exhibit the depth of water and the mud beneath; but in their report they state that after the first sounding, which they made 50 feet from the shore, the iron rod which they had prepared themselves with for penetrating the mud was lost, and they think it safe to estimate the depth of mud from 3 to 5 feet for the remainder of the distance, (1,530 feet;) an estimate which, it will be seen hereafter, is very far from the truth.

My survey of the river shows a line shorter than theirs, and at the same time exactly at right angles to the thread of the stream, and nearly in continuation of one of the streets of Georgetown.

Influenced by the decided superiority of this line over that selected by Messrs. Wright and Roberts, and coinciding in this opinion with Mr. Fairfax, the engineer of the Alexandria Canal Company, with whom I at that period acted, we applied to the mayor of Georgetown for the consent of that corporation to use that street as the northern abutment of the aqueduct, and we suggested to him the idea that it might be of advantage to the town to unite with the Alexandrians in constructing a roadway upon the piers of the aqueduct. This suggestion met with the decided approbation of the mayor, and he referred the subject to the councils, each branch of which appointed a committee to confer with the engineers; but the subject was not acted upon by those gentlemen. Six or eight months thereafter, however, when it became necessary to lay off the work for the contractors, they were induced, by the earnest solicitation of a gentleman of Georgetown, to meet the engineers on the ground. They were then unanimous in consenting to our using the street next west of the one designated by us; but not having power to act definitively, the matter was again referred to the councils, which took no further steps in the matter; and we were therefore necessitated to fix the abutment upon the site designated by Messrs. Wright and Roberts.

I narrate these facts that professional men commenting upon the position of the axis of the aqueduct, which is oblique to the stream, may be informed that neither Mr. Fairfax nor myself had any agency whatever in placing it where it is, but that, on the contrary, we were compelled, by circumstances beyond our control, to adopt it.

The borings for the foundations were conducted after the method by which the main or framing piles of the coffer-dam for the tide-lock at the western termination of the Caledonia Canal were fixed to the rock, only that we used a square box instead of a cylindrical one; that is to say, the box was formed of 3-inch heart pine-plank, 36 feet long, 8 inches in the clear inside, well jointed and banded with flat iron bars; the lower end of the box was shod with flat iron shoes, edged with steel, and fitted on the end of each plank, to prevent its being damaged by stones while driven to the rock; it was then driven in the ordinary manner of driving a pile, as far as it could be driven without crushing. It was then emptied by means of an auger made in the form of a quadrant of a circle, of the same diameter as the inside of the box; the circular side and one of the straight sides of this quadrant, for 18 inches of height, were made close, of thin rolled iron riveted to the ribs, which were fastened to the corners of the quadrant; from this proceeded an upright shaft, the other straight side being open to the bottom of it. Four flat teeth, each 2½ inches long, were fixed with an inclination downward, so that when the auger turned, these teeth loosened the sand and prepared it to enter easily into the body of the auger. To keep it steady while turning, there was fastened to the lower side of that corner of the quadrant which is the center of the circle, a pivot 6 inches long, which passed into the sand, and served as a center for the auger to turn upon. Immediately above this pivot stood the upright shafts, made of inch-square bars of iron, capable of being joined by male and female screws, 5 and 10 feet long, to any required length; upon this two cross-handles were placed to turn it with. A scaffold was erected by spiking strong pieces of timber to the deck of the pile-driver scow, their ends extending beyond the planes; planks were laid across these for a platform, upon which four men stood to turn the auger. From four to six turns, according to the nature of the stratum through which it had to pass, filled it. It was lifted above the top of the box by a purchase acting from the top of the pile-driver, and the sand was then cleaned out with a small shovel by a man standing upon the scaffold. At all the borings but one, where a stratum of coarse gravel 2 feet above the rock occurred, the box was driven to within a few inches of the rock; and in all cases where the box was emptied, a sounding-rod of iron, one inch in diameter, was dropped into it, which, rebounding several feet, proved that the solid rock had been reached.

At the point where the gravel occurred, about three-fourths of the way across the river, reckoning from the north side, the first attempt to reach the rock was ineffectual, the gravel caving in under the foot of the box as the auger was withdrawn; and as the box was required for other borings, it was thought unsafe to risk driving it through the gravel until the others were completed; but when they were, the box was brought back to the gravel-bank, and driven with great force until it began to spring or burst, although it had not yet entirely penetrated the gravel; it was, however, emptied to the foot, and a sounding-rod of iron was forced through the remainder of the gravel to the rock.

The box was always drawn by the crank of the pile-driver, with the assistance of double and single purchase-blocks. The number of borings were so multiplied as to prove the existence of rock under the entire bed of the river, at an average depth of 28 feet (instead of 15 feet as estimated by Messrs. Wright and Roberts) below the surface of ordinary high-water mark.

With the data thus obtained, a profile of the river was constructed, exhibiting the depth of water and mud to the rock.

The subject which next claimed the attention of the engineers was a plan for the proposed work. Having no instructions on this point, we were left entirely to the guidance of our own judgment, and to the influence of the facts which my survey and examinations of the site of the work had brought to view, and these were such as to induce us to give to the plan a character of the utmost stability as it respected the foundations, and one of equal durability to the superstructure.

It was to consist of twelve arches of stone, supported by eleven piers and two abutments; the arches to be 100 feet span and 25 feet rise; the soffits to be curves of eleven centers; three abutment-piers, being every third pier, to be each 21 feet thick at the springing of the arch; and eight piers of support, each to be 12 feet thick at the springing, the masonry of the land-abutments to be 21 feet thick. This plan was approved of by the president and directors, with the exception of the superstructure, the cost of which, being beyond the limited means of the company, was left for after consideration. The plan was further altered by rejecting the abutment-piers; but eventually these were restored on the recommendation of the engineers. A causeway of earth, 350 feet in length, was substituted for three of the arches at the southern extremity of the work.

The adoption of the causeway made a change in the arrangement of the piers necessary; and it was then decided that the aqueduct should consist of eight piers, 105 feet apart at high-water mark; two of them to be abutment-piers, each 21 feet thick, and six of them piers of support, to be each 12 feet thick, at high-water mark. The southern abutment to be 21 feet thick, with circular wing-walls, 13 feet average thickness at the base, 66 feet in length on each side, to connect with the slope-walls of the causeway. (See plate 1.)

The northern abutment, which is to be built by the Chesapeake and Ohio Canal Company, is not yet decided upon. Each of the piers to have an ice-breaker upon the upstream end, in form of an oblique cone, sloping forty-five degrees, extending 5 feet below, and 10 feet above, high-water mark, made of cut granite; the down-stream ends to be circular, and to have a batter or slope, the same as the sides, one inch to the foot. Upon this plan the work has been commenced, and so far progressed.

On the 29th of January, 1833, by the order of the board of directors, the engineer advertised for proposals to build the aqueduct upon the plan above described. Several offers were received, varying from $99,092.13 to $247,909.63. Among the number was one from Messrs. Martineau and Stewart, one of which firm (Dr. Martineau) afterward submitted a proposition for the coffer-dams alone, proposing to build them upon a plan which he claimed as being original, and eulogized it for its supposed economy, and for the facility with which it might be constructed. This plan was submitted to the investigation of the engineers, who, after a careful examination of the principle, reported against it, under the persuasion that it was incapable of being made water-tight, and insufficient to resist the pressure of so great a column of water as must have necessarily pressed upon it. At the engineer's solicitation, however, Colonel Kearney was requested by the board of directors to unite with them in their investigation of the plan. After a careful examination, he agreed with the engineers in the opinion of its total insufficiency.

During the winter and spring of 1833, the engineers were occupied in analyzing the various bids that were received, and which were from time to time reported to the board.

On the 8th of June, 1833, Messrs. Martineau and Stewart submitted a modification of their former bid, and the board of directors were influenced by the professional reputation of Dr. Martineau, and the most unexceptionable assurances of the integrity and pecuniary ability of Mr. Stewart, to accept it; and accordingly, on the 29th of June, a contract was signed by them, by which they undertook to construct the piers and southern abutment, agreeably to the specifications of, and under the direction of, the company's engineers; but the contract gave to the contractors a specific sum for each coffer-dam, whereby the engineers were necessarily precluded from interfering with their plan, and the one which had been reported against by them was then attempted to be built by the contractors. It was formed of two circular rims, 80 feet in diameter, and supported one above the other by posts; the lower rim rested upon the mud, the other at the surface of the water; each rim was formed of pine-timber, 12 by 14 inches, in segments of 10 feet in length, connected together simply by iron dogs; in the center of each segment a rabbet was made, through which a pile, with a 2-inch plank spiked upon the back, was driven to serve as a guide-pile; this divided the circumference into spaces or panels of 10 feet, which were afterward filled with piles of white pine, 11 inches in thickness, planed on the joints, firmly driven into the mud, but not to the rock. It was merely a single row of piles, without puddling to prevent leaks, and without shores to resist the pressure of surrounding water and mud.

The contractors evinced neither energy nor willingness to press the work forward, and it was not until the 2d of September, when they sub-contracted the work, that it may be said to have been commenced, although some materials had been delivered previously. On the 26th of September the circular frame of the dam was towed to its position on the axis of the aqueduct, and on the 2d of October it was weighted down to its place, bad weather having prevented its being done before that time; the driving of the piles around it progressed but slowly, there being but one pile-driver employed; and it was not completed until the 16th of November.

A steam-engine of twenty horse-power was placed upon a platform on piles, outside of the dam, on the down-stream side. December 13, the engine being in readiness, it was put in operation at low water, working eight pumps, capable of raising 500 cubic feet of water per minute. At the expiration of one hour, the water in the dam had risen 8½ inches, equal to the rise of the tide outside, whereby was plainly shown the impossibility of emptying it. Several other attempts were made to empty the dam, but with no better success than the first, when the winter set in, and put a stop to further operations.

By the breaking up of the first ice, with which came also a freshet, about the 21st of December, the dam was crushed; and the contractors evincing no greater disposition to secure their property than they had shown to advance the work, the board of directors, on the 4th of January, 1834, formally declared the contract abandoned, and directed their engineers to take possession of the contractors' property held in trust for advances made to them. They also directed the engineers to procure the machinery, &c., necessary for the vigorous prosecution of the work the ensuing spring.

In compliance with these directions, two steam-engines, of twenty horse-power each, were contracted for, as were also the vessels or scows necessary to receive the engines. Timber, stone, and cement were advertised for, and the building of three pile-drivers was immediately commenced, two of them calculated to be worked by horses, for driving the heavy oak piles, and the third, a light one, for driving the sheet piles, to be worked by a tread-wheel; a fourth, (received from the contractors,) worked in the ordinary way, by a crank, was repaired. A machine for excavating the interior of the coffer-dams was also ordered to be constructed by H. Smith, esq., of Alexandria.

Sixteen pumps were constructed, each of them formed of eight white pine staves, 3 inches in thickness and 38 feet long, and banded together with iron; they were 18 inches in the clear inside, at the upper end, and tapered 3 inches in the whole length, to facilitate the driving of the bands. At first they were left octagonal on the outside, but it being found very difficult to fit the bands, and make tight joints, they were afterward rounded on the outside, and circular hoops substituted for the bands, which had been octagonal, as well as the pumps. Narrow slips of cotton cloth, coated with white lead, were laid in the joints between the staves; the hoops 18 inches apart, well driven, made these perfectly tight.

The lower box or valve of the pumps was formed of a cast-iron plate, beveled on its edges to fit opposite angles of the octagonal trunk; on each side of it was a leaf composed of two pieces of plate-iron, between which was screwed a stout piece of leather, trimmed to fit the sides of the octagon; these two leaves were screwed to the cast-iron plate, the leather being the joint or hinge. In the top of the cast-iron plate a ring was formed for the purpose of hoisting out the valve; in the lower part of the plate was another ring or hole through which a rope was passed to draw it firmly into its place in the pump, and when there, an iron screw-bolt, one inch in diameter, was passed through the pump at right angles to the valve, and underneath it, to prevent its being forced farther down by the column of water. The upper bucket was an inverted cone, 27 inches in length, and of the same diameter as the pump, made of two thicknesses of sort leather, well sewed together, through which was passed an iron rod 1 inch thick and 7.4 feet long, projecting below the vertex of the cone 26 inches, upon which were placed leaden weights, secured by a screw-nut on the end. The rim of the cone was divided into spaces corresponding with the octagonal sides of the pump, to which were secured rings by means of straps of iron, 1 foot in length, passing in and outside, and riveted through the leather by flat-headed rivets. To these rings were hooked chains, which were suspended from the iron rod just below the eye or ring at the top; through the ring at top was hooked a 7-inch rope of white hemp, which passed over a cast-iron grooved sheave, 3 feet in diameter, placed immediately above the pump, and thence under another sheave of the same diameter, to the steam-engine which worked it. On the first opening of spring, (March 1, 1834,) preparations were made for removing the circular coffer-dam built by the contractors, Martineau and Stewart. On the 4th of March the first pile was drawn, and on the 26th the whole of that dam was removed. The piles were drawn by means of derricks or shears erected on scows, by a winch bolted to the deck of the scow, and by double and single purchase-blocks. Two of these derricks were employed, and sometimes it was necessary to attach both of them to one pile; sometimes a lever was used to draw the piles; ordinarily, however, the single winch, worked by six men, was sufficient.

Experience in founding upon rock, at so great a depth, is very limited in this country, there being but one example, viz, the bridge over the Schuylkill, at Philadelphia, and that not strictly a fair example, the rock not having been entirely laid bare. I take the liberty of extracting from the report of the building-committee some notices of the difficulties which beset that work:

"A well-intended, but mistaken, endeavor to excavate all the silt and mud out of the dam was arrested in time to save the whole from ruin.

"The balance of pressure of the exterior head of water was perceived to be on the point of being destroyed; and the attempt of a total removal of the whole contents of the dam was fortunately discontinued. The president, who, by constant attention, was minutely acquainted with the principles and construction, and, of course, the forte and foible of the dam, became uneasy, and intimated to the mason that the prosecution of the attempt of the total excavation was dangerous in the extreme. The mason was convinced that the opinion was correct, and the superintendent declared he had long been apprehensive of the consequences.

"At length the critical period arrived when it appeared highly probable that another day's work would have defeated the whole enterprise. It was known that nothing but actual perception of the consequences would bring conviction, which all reasoning (resisted by the strong desire to reach the rock) had failed to produce. Several of the stoutest laborers were set to work, with a view to dig a pit to the rock, which was not more than 3 or 4 feet from the then surface; they had not pierced the mud above one-half its thickness before a column of water, copious and alarming, suddenly gushed up; this produced an immediate conviction of the unjustifiable hazard of any further attempt to bare the rock; and the factitious foundation, being without further hesitation agreed to, was forthwith commenced."

No descriptive memoir or drawings of this work ever having been published, nor of the London bridges, (the deepest foundation, perhaps, in Europe,) the engineers, therefore, had to proceed with the greatest caution; they were aware of the very exposed situation of the work, and impressed with the absolute necessity of founding it directly upon the rock; the difficulties and dangers of the attempt, although they were foreseen, were deemed subordinate to the great object of stability; and in this view they were promptly sustained by the president and directors of the company.

The coffer-dams for the construction of the bridges of Neuilly and Orleans, designed by the distinguished Peronnet, were selected as models; but as these dams were for foundations of comparatively little depth, or such as were supported by piles, and where the water only was required to be emptied, alterations were found to be necessary to make them suitable to the great depth to be reached in this case.

The coffer-dam first undertaken was to occupy the position of the pier No. 2, reckoning from the Virginia shore, and the next north of the one intended to have been built in the circular dam of Messrs. Martineau and Stewart, in a depth of 18 feet water and 17 feet 4 inches of mud.

The figure of the dam, a parallelogram 82 feet long by 27 feet wide, inside. The first pile was driven upon the axis of the aqueduct, which had been carefully established, and its distance from the southern shore carefully measured by means of a straight graduated float, on the 16th of May.

The inner row of piles were of white oak, 40 feet long, 16 inches diameter at the larger end, shod with iron pointed with steel, weighing twenty-five pounds; they were placed 4 feet apart, from center to center of each pile, and driven to the rock with a ram weighing 1,700 pounds. These piles were connected on the inside by a pine stringer 1 foot square, bolted with iron screw-bolts passed through each of the oak piles; the corners were secured by a strong iron strap with a jib and key.

The outer-row of piles, 15 feet from, and parallel with, the inner-row, was also of oak, 36 feet long, and 16 inches in diameter at the larger end; they were placed 4 feet apart, from center to center, and pointed, but not shod nor driven to the rock.

These were likewise connected by a pine stringer on the outside, 1 foot square, screw-bolted to each oak pile; the up-stream angles of the dam were cut off, so that the outer row of piles formed a hexagon; the angles were secured by the stringers overlapping each other 3 feet, and halved on to each other.

These piles were driven without bands on the but-ends, as is customary. A method recommended by G. Whistler, esq., formerly of the Army, was adopted, viz: the but-ends were made concave three-quarters to one inch deep with an adz, and covered with a thin piece of sheet-iron simply laid on, by which means a pile, it is believed, may be driven to any depth without injury.

Upon the two rows of oak piles, or rather upon the stringers, a scaffold was erected, upon which the pile-drivers were placed for driving the sheet-piles, (pile-plank,) which were of the best North Carolina heart pine; those for the inner row were 40 feet long and 6 inches thick; they were driven in panels (montants) of 16 feet, formed by bolting (the bolts having room to play) two pieces or guides, 18 feet long and 12 by 6 inches, to two pile-planks, 8 feet from the foot, the pile-plank between the string-pieces or guides; the piles were then suspended in the planes of the pile-drivers, placed at the proper distance apart, and lowered in their places, the guide-pieces sliding against the oak piles; it was then driven by slight blows of two pile-drivers, the ram of one resting upon the pile, while the other made a blow, and so alternately until the cross or guide pieces rested upon the mud; even moderately long blows were found either to shatter the pieces below or to break the bolts which connected them. Two other similar pieces were then placed near the top of the "montant" piles, 1 foot above high-water mark, and the whole of them were screw-bolted to the oak pile behind it. When these panels were fixed around the inner row of oak piles, the sheet-piles were driven so as to fill each, commencing at each end of them and continuing toward the center, the last or center pile being wedge-shaped; the others were hewn and jointed, with parallel sides, by means of a plane; they were sharpened like a wedge and beveled on one corner to force them into their places against the adjoining pile; although not shod they were driven to the rock. The sheet-piles of the outer row were of the same dimensions as the inner row, but they were only 36 feet long; they were prepared and arranged in the same manner as those of the inner row, but they were not driven to the rock. (See Plate 2.)

An earnest desire to husband the company's funds as much as possible was the leading motive for using short piles for the outer side of the dam. It was hoped that if these were driven a few feet (12 to 15) into the muddy bottom of the river, they might prove to be sufficient for the support of the puddling, at least until the interior of the coffer-dam should be so far emptied as to cause the preponderance of pressure to proceed from the outside towards the interior; and the experiment was the more readily attempted, inasmuch as the means were at hand to give additional strength to this part of the work. It proved, however, that the outer row of piling ought to have been driven to the rock.

The ram used for driving the sheet-piles weighed 1,300 pounds. Two pile-drivers were employed driving the sheet-piles—one worked in the ordinary way, by a crank, the other by a tread-wheel; the latter proved to be so superior that the former was altered into a tread-wheel. The crank required eight men and a superintendent, and made a blow from the top of the planes (40 feet) in seven and a half minutes, while the tread-wheel required but six men and a superintendent, and made a blow from the same height and with the same weight in one minute and fifteen seconds. The horse pile-drivers made a blow in one and a half minute. Both rows of sheet-piling being completed, ties of 11 inches square, pine-timber, were put in to connect them together; these ties were placed 12 feet apart, and were dovetailed into the heads of the sheet-piles; this, from the apparent stiffness of the oak and sheet-piles, was deemed to be sufficient; but when the puddling came to be thrown in, the weight of the clay forced the outer row to spring out, drawing the ties through the dovetails. Additional ties were therefore put in at every other oak pile, and they were notched on to the "montant" pieces and secured down by rag-bolts; and even these were found not to be sufficient to hold the rows of piles together, for, as the puddling advanced, in many places the ends of the ties split off, and it became necessary to pass long and strong screw-bolts through the stringers of both rows of piles. This being done, the dam might have been deemed to be secure; but it even became necessary as an additional security to place stringers outside of the sheet-piles, to notch them on to the ties, and to rag-bolt them down entirely around both the rows, and even to place three long ties, of 14 inches square timber, entirely across the dam to keep the long sides together; this was done by driving two oak piles contiguous, outside, and touching the outside stringer, two others immediately opposite on the other side of the dam; each pair of piles being connected together by a stout piece of timber across and bolted to them. The long ties which crossed the dam were formed by scarfing timbers, were notched on the cross-pieces, and secured to a pile at each end by stout iron straps.

These securities were the more necessary because the stringers, ties, &c., were of white pine, which had been left in the circular dam and which it was necessary to use.

June 14. The oak piles of dam No. 2 being all driven, preparations were made for building one for the pier (No. 1) next the Virginia shore, upon the site that had been occupied by the circular coffer-dam of Messrs. Martineau and Stewart; this dam was upon the same plan as that of the dam for pier No. 2.

It would have been well if we could have waited to profit by the experience to be gained in employing No. 2, but it was then believed that two piers might be built within the year, and we had to proceed with both. Our experience, however, had taught us to guard more effectually than heretofore against the expansion of the clay-puddling, which tended to force the outer and inner rows of piles apart. Ties were, therefore, placed at every oak pile, and they were notched on to the string-pieces and were rag-bolted to the stringers and oak piles.

Large timbers (14 inches square) were laid from the center of the outer row of the sides of the dam, crossing the corners to the center of the outer row of each end, and they were notched on and bolted to every timber they crossed; these ends, too, were made to cross, and were halved into each other and were secured by a bolt. Two long tie-pieces were then placed entirely across the dam, dividing it into three equal parts, and notched and well secured. The up-stream ends of this dam were left square, great difficulty having been experienced in cutting off the corners of the other dam; and the angles were secured by a second set of stringers placed upon the tie-pieces of the outer and inner rows of piles and bolted to the oak piles; they passed and were halved into each other at the corners of the dam; these stringers were continued entirely around the dam, and a piece was also placed at each corner to connect the exterior and interior pile of the angles as in Plate 3.

The puddling of dam No. 2 was then brought up to a level with the tie-pieces, and two pumps were placed in the down-stream end of it; they were octagonal-shaped, and were shortened to conform to the then depth of water, and were placed in the dam for experiment; they were found, however, to be quite sufficient to discharge the water as low down as the original surface of the mud.

On the 2d of September a trial was made of the pumps, which did not prove to be very satisfactory owing to the stretching of the ropes and the breaking of the straps, &c., (leather straps being first used for the buckets, for which chains were ultimately substituted.) On the 3d of September another trial of the pumps was made, more successful than the first, although the machinery still worked imperfectly.

The pumps were worked by ropes passing over grooved sheaves 18 inches in diameter, attached to a drum 4 feet in diameter on the steam-engine; the drum, by a reciprocating motion, caused one bucket to rise while the other descended. The length of the stroke of each pump was 6 feet, and the engine at first made twelve strokes per minute, and lowered the water in the dam at the rate of 2 feet per hour. The speed of the engine was then increased to fifteen strokes per minute, and was continued at that speed for one and a half hour, in which time the water was lowered 1 foot 10 inches more.

The dam being now in some danger from the pressure from without, the pumping was discontinued, and additional shores were placed against the stringers, and preparations were made for placing a second tier of shores 8 feet below high-water mark.

On the 6th, after some further alterations and the ropes being well stretched, another trial of the pumps was made, and in fifty-six minutes' time the water was lowered 3 feet; but still the discharge was only 4.1 cubic feet per stroke of 6 feet, while the capacity of such a stroke was in fact 8.2 cubic feet—a diminution of one-half being attributable to the leakage of the pumps and the imperfect working of the buckets. On the 8th of the month the second tier of shores being prepared, the water was lowered 2 feet in one hour and eight minutes, so as to admit of their being placed, and they were placed on that day, the carpenters working until 10 o'clock at night.

On the 9th the water was lowered 2 feet 6 inches in forty minutes, and it being now 9 feet 6 inches below the high-water level, the weight of the puddling was such as to cause the sheet-piles to spring inwards; short pieces of timber were therefore wedged in between the oak and sheet piles, extending from oak pile to oak pile to support the sheeting.

On the 10th the water was reduced in depth 2 feet in forty-five minutes, and on the 11th 4 feet in fifty minutes; the pumps discharging 6.87 cubic feet per stroke, working at fourteen strokes per minute. The leakage of the dam at this time was observed to be 1 inch per hour.

So frequently were accidents happening to the machinery and pump-gearing that the time of pumping in each day rarely exceeded the time above noted.

The dam being now entirely emptied of water, a third tier of shores was placed this day at the surface of the mud.

The excavating machine was put into the dam. This machine consisted of an endless chain of buckets working vertically over and under square drums of cast iron, fixed at top and bottom in a frame of four upright pieces of timber 45 feet long; this frame was suspended on a movable axis, resting upon a carriage which was movable on a railway crosswise of the dam; and this railway was upon a carriage likewise movable upon a railway lengthwise of the dam. The breadth of the sides of the square drums corresponded with the length of the links of the chain.

Upon the axle of the upper drum a cam, and near it an open box or hod, was fixed, to receive from the buckets and discharge into an inclined trough the matter brought up by the machine.

This contrivance worked well, and preserved a constant communication between the buckets and the scows which were stationed under the lower end of the trough and alongside of the dam.

The excavating-apparatus was worked by an endless rope passing around a drum on the steam-engine scow; a bevel-gear (fixed upon the carriage which moved lengthwise of the dam) changed the direction of motion by another endless rope passing around a drum upon the machine itself.

This machine being in readiness, a trial was made of it on the 2d of October, which was not very successful, for it was found to be a very difficult matter to give to the endless chain its proper degree of tension; it broke on the first trial from the great resistance it met with in dredging.

On the 3d and 4th it was tried again, but it still worked indifferently, and was found to be extremely difficult to be moved upon the railways owing to its very great weight and especially when it became clogged with mud.

To move it from space to space between the shores, where only it could operate, it was necessary to lift it over the shores, and this was attended with very great delay.

The intention of using it as an excavator was therefore abandoned, and it was fixed within a few feet of the pumps and used as an elevator; laborers with shovels being stationed in the dam to fill its buckets. As an elevator it proved to be useful, although it was yet not without its inconvenience; the men were sometimes unwilling to work under it, as they often were exposed to the falling mud and water.

In addition to this machine, a windlass was erected across the dam near its upper end; it was also worked by the steam-engine, and was capable of raising four buckets at once, each containing 4.6 cubic feet. The horse pile-drivers were stationed at the center of the dam and were also used for hoisting out mud. By these means 6 feet depth of mud was removed by the 22d of October, notwithstanding the frequent interruptions from the machinery getting out of order.

At this period it was discovered that several oak piles on the south side of the dam were broken, and that the great pressure had caused the braces at the end to crack; this created great alarm among the laborers below. Immediate steps were taken to secure the work, by doubling the number of shores at the original surface of the mud, and by placing another tier (fourth) at its then surface; but, before this could be fully accomplished, (viz, on the 30th,) a leak occurred in the northeast corner of the dam, which soon filled it. This leak was caused by the great weight of the column of water on the outside forcing the mud from beneath the puddling into the dam under the foot of the "montant" piles, which, as before remarked, were not driven to the rock. The puddling soon after settled down and stopped the leak, and the vacancy at top was filled up.

The following day the pumps were at work again, and had lowered the water 8 feet, when the crank-wheel of the engine broke, principally, no doubt, owing to the smallness (18 inches diameter) of the sheaves over which the pump-ropes moved, too great a strain being thus brought upon it; these sheaves were taken out, and others, of 3 feet diameter, were substituted. The crank-wheel was replaced by a new one November 1, and on the 2d all the water was pumped out of the dam, and the carpenters resumed the business of shoring.

The dam was not now so tight as it had been heretofore; several small streams of water came in around the down-stream end, notwithstanding which, one pump was found to be sufficient to keep down the leakage, and enabled the carpenters to work with comfort.

During the night of the 3d, while the pumps were at work, a large leak opened at the southeast corner, from the cause heretofore mentioned, and filled the dam, no work-men being in it at the time; the leak was not discovered soon enough to stop the pumping before the sand had accumulated above the heel of the pumps. The increased strain thus brought upon the pump-ropes broke the crank-shaft, and this derangement of the engine caused the breaking of the flange of the fly-wheel. On discovering the condition of the work, the pumps were hoisted out of the dam and cleared of sand; the repairs of the engine were immediately commenced, and an alteration was made in the pumps by cutting holes in them for the discharge of the water a few inches above the level of the dam; heretofore it had been discharged at their full height.

On the 5th the pumping was again resumed, and 17 feet 4 inches depth of water was discharged by two pumps in 4 hours 32 minutes working-time, or at the rate of 3 feet 10 inches per hour.

The puddling, which had settled down 5 feet, was replaced; and this increased weight of clay caused the stringers of the outer row of piles to break, and the wall of the dam, of course, to spread a little.

It was now that the long ties, heretofore described as extending entirely across the dam, were put in.

The weather having by this time become very cold, and indicating an early winter, it was thought prudent to make preparations for protecting the dams against the floating ice which the freshets might carry against them. Accordingly, an ice-breaker was commenced a short distance in advance of each of the dams.

Although the intention of emptying dam No. 2, and commencing the masonry, if possible, this year, was by no means abandoned: on the contrary, it was resolved to prosecute the work night and day, and on the 8th the excavation was resumed. Some delay was caused, however, by the last incursion of sand, which had accumulated about the pumps, so that the water could not be entirely pumped out, and it had also buried up the lower buckets of the mud-machine; these were soon relieved, however, and the machine was actively at work until the afternoon of the 10th, when the crank-shaft of the engine working the pumps was again broken; the other engine, working the mud-machine, was kept at work raising water only, and it was found sufficient to keep the leakage under, so that the carpenters could work below.

The crank-shaft of the broken engine was replaced that night, and a gang of laborers were employed also during the night in removing the sand from around the pumps. On the 11th the pumps were lowered, and the dam was entirely drained of water. The windlasses, for raising mud, at the upper end of the dam, were again put and continued in active operation, although frequent interruptions were caused by the breaking of the pump-ropes. As the height to which the water had to be raised increased, these ropes were found to be too weak, and their size was increased to 6 inches.

At this time W. M. C. Fairfax, esq., the engineer of the Alexandria Canal Company, who had been heretofore associated with me on the work, acquainted me with his intention to retire from the service of the company, a resolution which I learned with much regret, as he was a well-informed and very efficient engineer, and our intercourse had been always characterized by much harmony of opinion and feeling.

The excavation went on very actively and without interruption until the 15th, when the leak sprang again in the southeast corner; the water rushed in very copiously till it reached the lower tier of shores, when the puddling on the south side settled down 2 feet below the tie-pieces, for two-thirds of the whole length of the dam, and the leak then diminished.

The weather being at this time very stormy and cold, the laborers were very reluctant to work, and in the afternoon one-third of their number refused to return to it; those who did, were employed in replacing the puddling; but that night not a laborer could be induced to turn out.

The superintendents, carpenters, and blacksmiths were therefore sent on the dam to hoist the pumps out of the sand, and at midnight one pump was at work.

The next morning, there being no abatement of the storm, the laborers still refused to work, and the mechanics were again sent in their stead to raise the other pump; and this was done during the day, and the dam was then drained as low as the last incursion of sand would permit.

One pump, which was sufficient to keep down the water, was kept at work during the night in the hope that the weather on the ensuing morning would be more favorable; but the storm still continued, and snow having fallen previous to the rain, there could be no doubt but that there would soon be a freshet in the river. It was therefore thought prudent to secure everything about the work, and as laborers could not be procured for that purpose the mechanics again cheerfully undertook this duty also. The current already in the river being too strong to attempt the removal of the steam-scows, scope was given to their fastenings and they were allowed to swing under the lee of the dams.

The pile-driver scows, the large crane scow, and some of the smaller scows were moored under the lee of the causeway of the aqueduct; but after six hours' exposure to a pelting rain, which froze as it fell, and in the night, too, we were forced to return to the shore and leave the others to take their chance, secured to the dams as well as they then could be.

During the night several of the scows were swept from their moorings and driven ashore, and, as had been foreseen, the freshet rose over the sunken puddling and filled the dam.

November 18.—The weather cleared off, but the laborers did not return to work at the usual hour; but during the day a small force was raised and set to work to get off the scows that had been driven ashore. On the 19th this force was increased and employed in boating clay to replace the puddling which had sunk in the dam.

On the 20th a large force of laborers was raised and employed in boating clay, and at noon the repuddling was completed and the pumps were in readiness for work. The dam was pumped out during the night; but on the morning of the 21st the leak in the northeast corner opened again, and spouted copiously for a few minutes; the puddling then settled 1 foot and the leak ceased. The weight of the puddling on the south side caused the dam to spread a little more, and additional long ties were therefore placed across it.

The pumping was continued during the night of the 21st until the segment wheel of the pump-gearing broke; but it was soon replaced by the one from the other engine and the pumping continued.

In the afternoon of the 22d the leak in the northeast corner increased, the dam filled, and the puddling settled* 2 feet.

I had been much disheartened by these frequent leaks and incursions of sand; but it had now become very apparent that the whole mass of mud and sand underneath the puddling would be washed into the dam, and that on its being replaced by the clay puddling the dam would become tight.

But notwithstanding this conviction, it was not very pleasant to recollect that the other dam (No. 1) was constructed upon precisely the same plan as this, and that consequently the same difficulties might be reasonably anticipated with respect to it. But I now felt quite convinced that by perseverance all difficulties could be overcome, and the ultimate success of the work insured. I was very much encouraged, also, by the confidence of the president and directors and their advice to persevere.

Sunday, November 23, was very boisterous, and it was with great difficulty that clay could be boated to the dam, especially with so small a force as could be induced to attend; one pump was at work, and at 4 o'clock in the afternoon the water was down to the lower tier of shores when the crank-shaft of the engine broke. During the night it was so stormy that it was impossible to keep lights to hang the crank-wheel upon another shaft. These frequent fractures of the machinery were attributed, and I think with reason, to the intensity of the frost.

On the 24th the water in the dam had risen but 22 inches in fifteen hours, during which time the pumping had been suspended; the crank-shaft was replaced and the pumping was resumed; but the weather was so boisterous and cold that the laborers could not be persuaded to go into the dam. On the 25th, in the afternoon, four men were persuaded by the offer of high wages to go below and clear the sand from around the pumps, but working at night was entirely suspended by the difficulty of procuring laborers.

On the 26th the laboring force was increased to eight men, who were employed clearing away the sand from the pumps and in throwing it to a convenient place to be raised by the machine. The force was increased gradually and the excavation now progressed very well. On the 3d of December the rock beneath the mud was touched by one of the shovelers about the center of the dam; at dark, when the laborers left off work, the dam was perfectly dry; it was examined all round, and no appearance of a leak was discovered. At 9 o'clock a noise was heard, of which no notice was taken by those who attended the steam-engines and pumps, but at 1 o'clock in the morning the superintendent of pumping discovered that the dam was full of water (a leak having opened in the up-stream end) and that the puddling had settled down 5 feet. The next morning the whole force was employed in boating clay to renew the puddling, and the pumps were tried but without effect; the tide ebbed and flowed in the dam. At 2 o'clock p. m. the puddling was raised nearly to the tie-pieces, and the pumps were tried again with better success than in the morning. The water was lowered 6 feet 4 inches in one hour and forty-five minutes; the pumping was continued during the night, and on the 5th the dam was entirely free of water and the windlasses at work hoisting out mud. This last incursion of sand and mud was comparatively small; it was all removed at noon; but while the laborers were at dinner the leak opened again and the dam filled. The puddling settled below the tie-pieces, but it did not stop the leak. The pumps were tried at intervals throughout the night, but without effect; and the tide continued to ebb and flow in the dam until the 8th, when the puddling at length settled down and the water was pumped out.

---

* At sunset the pumps were at work again, and the water was lowered very rapidly; but during the night the dam again filled, and another settlement of the puddling took place.

On the 9th soundings were taken to determine the quantity of mud yet to be removed, and it was found to be 350 cubic yards; the surface of the rock very uneven.

The excavation progressed very well until noon the next day, when several leaks occurred at once on the south side and the dam filled. On the 11th the puddling which had sunk was replaced and the dam pumped out again.

The excavation was resumed, and all the sand that had been washed in under the "montant" piles was removed.

It was ascertained that this last incursion of sand came from the outside of the dam as well as from underneath the puddling, and that the outer row of piles had settled down 5 inches, whence it plainly appears that the outer as well as the inner row of piles ought to be driven to the rock.

The dam was now tight, and the excavation continued until the 19th with occasional interruptions from the breaking of the machinery, which we attributed to the frost. On the 14th the puddling on the south side settled 3 feet, but this caused no interruption to the work.

On the 15th the river was covered with ice, the water in the supply-pipe of the engine was frozen and the flanges of the steam-pipe broke. These were soon repaired, and in the afternoon the windlasses were at work. On the 17th a large force was employed at the excavation, and both the machines and the windlasses were at work until noon, when the loss of steam, occasioned by the break in the steam-pipe, rendered the engine incapable of working, and the excavation was consequently suspended. While the engine was being repaired another set of shores was put into the dam.

On the 19th the repairs to the steam-engine were completed and the windlasses at work; the rock for several feet at the upper end of the dam was entirely laid bare.

A small leak was observed on the south side near the upper end, but it soon ceased. Orders were now given for a boat-load of stones to be brought alongside of the dam, and other preparations to be made for commencing the masonry the next day. A small force of laborers was persuaded to remain through the night to wash off the rock and have everything in readiness for the masons in the morning; but at 11 o'clock the leak which had threatened us in the morning burst in with great violence and the dam was filled with water in twenty minutes' time; the puddling then sank down 4 feet.

On the 20th of December the whole of the force was employed in boating clay to replace the puddling; the pumps were also tried, but without effect.

At 2 o'clock p. m. the puddling was raised sufficiently high to keep out the tide. At ebb tide the water remained at a higher level in the dam than in the river, consequently the leak was stopped.

The pumps were now started again, and at the expiration of one hour the water was lowered 2 feet 11½ inches, and the pumping was ordered to be continued during the night; at 10 o'clock the connecting-rod of the engine broke and caused some delay.

On Sunday, December 21, the water in the dam was lower than the lower tier of shores; but the segment-wheel of the pump-gearing breaking, and another leak having sprung on the north side, the dam filled again.

It had been in contemplation, and arrangements had been making for some time past, to alter the mode of pumping by taking out the drums and substituting a crank motion All the fixtures for this purpose being in readiness, that alteration was now made.

December 22.—The puddling was replaced and the tide shut out at low water, and the tide did not rise in the dam. But the alterations of the engine and the consequent changes in the sheaves for the pump-ropes were not completed until midnight of the 23d, at which time the pumps were put in motion. The new crank worked very well, but the pumps were soon choked with sand, and it became necessary to hoist one of them out.

On the 24th the pumps were at work again, but the weights attached to one of the buckets broke off. The other was kept at work, and the water was lowered rapidly, showing the dam to be tight.

On the 25th the dam was entirely free of water, and the excavation with the windlasses was resumed, and the carpenters were employed in placing another tier of shores near the surface of the rock.

The weather being very stormy (December 29th 17 inches of snow fell) but a small force of laborers could be kept at work, and they were employed in assisting the carpenters with the shoring.

January 1, 1835.—The weather having moderated, the mud-machine was set to work again, and we were enabled to lower down the pumps so as to drain the upper end of the dam to the bottom and clear off the mud.

January 2.—The men who were excavating around the foot of the pumps touched the rock with their shovels.

The dam being now in very fine condition, preparations were again made for commencing the masonry, and on the 3d the mud was entirely washed off the rock for one-half the length of the dam; the surface of the rock was seen to be extremely irregular, as if it had been worn into deep cavities. On this day, also, the masonry was commenced.

The pumps were lowered so far as to rest upon the rock; the mud-machine, too, was lowered to its utmost extent, but it was found to be too short to reach the bottom, being over a deep cavity in the rock. There remained in the dam, however, but a very small quantity of mud in the cavities of the rock. It was determined to remove the machine and that the windlasses should take its place.

About fifteen cubic yards of masonry were laid this day in hydraulic cement, and the pumps were not worked during the night that the masonry might be covered with water, although there was no apprehension of its being affected by frost at so great a depth. The night proved to be extremely cold, and on Sunday, January 4, the river was covered with ice sufficiently strong to bear a man.

Being thus cut off from a supply of stone, a stop was put to the masonry and all our other operations.

Every effort was now directed to the removal of the machinery and to placing it in a state of security. The steam-scows, pile-drivers, mud-scows, &c., were removed, and they were drawn upon the flats near the causeway of Analostan Island and under the lee of the causeway of the aqueduct. The pumps, mud-machine, and windlasses were taken on shore.

The dam (No. 2) was covered with sheet-piles treenailed to the ties and shores, with an inclination down stream to facilitate the passage of the ice over, and to prevent its falling into the dam should the freshets rise to that height.

The puddling of dam No. 1 was brought up to the level of high-water mark, and the ties, shores, &c., secured.

The ice-breakers to both dams were completed. This being done, the campaign of 1834 closed.

1835.—Although the winter had been extremely rigorous, and a great quantity of ice had formed in the river, it passed off without the slightest injury to the coffer-dams, which were therefore in good condition for recommencing the work early in the season. The campaign, however, did not open until the latter end of April. Congress having declined further aid to the work, funds were raised by individual enterprise, the citizens of Alexandria, with their usual public spirit, subscribing the amount required by the engineer for the operations of the year, and on the 21st of April the board of directors ordered the work to be resumed.

On the 22d of April a small force of carpenters and laborers was engaged in stripping dam No. 2 of its winter covering. The pumps were put in place; the steam-engines were brought back to their positions at the dam; windlasses were erected for hoisting out the small quantity of mud remaining in the dam; the railways were laid, and a double derrick for hoisting in large stone was placed upon them.

These arrangements being completed, the pumping was recommenced on the 14th of May, and the dam was entirely freed of water to the rock in ten and a half hours with only two pumps, and it was found to be perfectly tight.

It is worthy of remark, as a proof of the tightness of the dam, that for a space of nearly four months the water inside did not reach the level of high-water mark by 22 inches.

On the 15th the windlasses were at work hoisting out mud, and the masonry was begun. The stone laid in the winter was found to be very solidly united, the cement having a most excellent set. To insure the safety of the dam the masonry was now extended to the oak piles so as to cover the entire space within, excepting a few feet at the down-stream end where the pumps were placed.

On the 17th the mud was all removed and the rock entirely bare. The windlasses were now removed and the railway extended to receive another double derrick.

The railways were constructed thus: 12-inch square timbers, of heart-pine, were placed parallel to each other over the heads of the inner row of oak piles and firmly secured to them lengthwise of the dam; flat iron rails were placed on the inner edges of the timbers, and upon these were placed two carriages of timber.

One end of each carriage projected 10 feet beyond the dam over the scows ladened with stone; these ends were stiffened with braces of iron. Iron rails, the profile of which was a semi-circle, were laid upon the carriage, and upon these the double derricks which moved on grooved wheels fixed under each foot. Level with the base of the pyramid or derrick a platform was extended upon which the winch for hoisting was placed. The derricks were each worked by four men and a boy—the men at the cranks and the boy at the slack of the rope to take it up as it wound upon the drum. Stones weighing from three to four tons were, by these means, hoisted up and lowered into the dam with great ease.

I am indebted to Lieutenant Bartlett, of the Corps of Engineers, for the plan of the wheels of these derricks.

The maximum number of masons capable of working to advantage was now employed, and their confidence in the strength of the dam was such that they worked without the slightest apprehension of danger, and the pier rose rapidly under their efforts.

A spectacle so unusual as that of men busily at work so far below the surface of the river seemed to interest the public exceedingly; but to the engineer, whatever might be his confidence in the ability of the dam to resist the immense weight which he knew to be constantly pressing upon it in the most insidious form, the sight was one which filled him with anxiety and urged him to the most unceasing watchfulness.

The masonry was carried up perpendicularly until it reached the second tier of shores from the bottom, where it was made to assume the shape and dimensions originally designed for the pier.

It being considered too hazardous to take out the lower tier of shores, they were built in with the masonry; but as the masonry reached successively the shores above, the sides of the dam were braced against the wall and the shores taken out.

The greatest pains were bestowed in tempering the cement and ascertaining the proper proportion of sand. Care was taken, also, in selecting stone of good quality and of large size; none were admitted whose beds did not exceed the faces at least four to six times, not only on the face of the work but entirely through it. No small stone were used except to fill up the spaces formed by the irregular shapes of the large ones, and the whole was well bedded in cement; no grouting was permitted. Cement was used to the height of 2 feet above high-water mark, and above that common lime mortar; the whole was pointed with cement.

The ice-breaker at the head of the pier is of cut granite from Sandy Bay, Massassachusetts. The two lower courses, commencing 5 feet below high-water mark, were 22 inches thick; and the remainder, 10 feet above high-water mark, were 18 inches thick; no stone being of less size than 20 cubic feet, and the whole was laid in cement.

On the 21st of June the masonry was on a level with the top of the dam. The derricks, railways, &c., were then removed, and two booms were substituted for them to raise the masonry to the intended height, 29 feet above the plane of high water.

Notwithstanding a delay of some days occasioned by a breach in the canal, which cut off the supply of stone, and the time occupied in removing the derricks and railways and erecting the booms, the pier was completed on the 1st day of August. As the masonry advanced the pumps were but seldom used, the water being allowed to rise with the masonry in order to give a set to the cement; and when there was no longer a necessity for pumping at dam No. 2, the engines, &c., were removed to dam No. 1, arrangements for the pumping and excavation of which having been in progress for some time.

The machine used last year for raising mud proving to be so unwieldy it was determined not to use it again, and in its stead windlasses were erected over the center of the dam lengthwise of it. They were worked by the steam-engine, and were capable of raising nine buckets at a time; they were found to be much more expeditious in raising mud than was the machine, and they were much less liable to get out of order.

The puddling which was left last year on a level with high water, was filled up to a level with the ties at the top of the dam. The shoring required for the depth of water was arranged in the dam ready to be fitted and keyed up as the water lowered them to their places.

On the 20th of June the President of the United States and the members of his Cabinet having honored the work with a visit, the two pumps in dam No. 1 were set to work, and performed admirably, and lowered the water very fast; but it being intended merely as an exhibition of their powers, the pumping was not continued long, as the shores were not quite ready to be keyed up.

On the 23d the water in dam No. 1 was lowered to the level of the second tier of shores. The oak piles being very irregular, a great quantity of blocking was required between them and the sheet-piles; the blocking was also necessary to bring a proper bearing upon the stringers of the shores, which, in consequence of the want of bearing, were not keyed up until the day after that work was done.

On the 26th the water was pumped out to the mud, and the third tier of shores was placed.

This dam did not prove to be so tight as was No. 2; at this stage of the work several small leaks were observed around it, and one pump was constantly required to keep down the water.

On the 27th the shores of the third tier were keyed up, and the excavation was commenced. The machinery of the windlasses, however, soon required overhauling and arranging, but on the 29th the excavation was continued.

On the 30th the leaks increased, and the excavation was discontinued. The laborers were employed in boating clay to replace the puddling, which had settled a little.

July the 1st the excavation was resumed; but the leaks increased beyond the capacity of the pumps, and the dam filled.

The difficulties encountered in this dam presented themselves at a much earlier period than our experience in dam No. 2 could have led us to expect, and they were of a much more serious character. This is attributable, mainly, to the fact that the puddling, a very tenacious red clay, had been in the dam so long as to become too compact to settle down and fill the cavities formed by the water which undermined it.

The first leaks that occurred were through open joints in the sheet-piling. Various expedients suggested themselves for stopping these leaks; the first was to drive a sheet-pile through the puddling to cover the open joint, but it was foreseen that the "montant" or sash-pieces resting upon the mud would prevent the pile from coming in contact with the sheet-piles to cover the open joint; it was therefore not tried. The next was to turn the pumps upon the puddling, so that by softening it and increasing the weight somewhat, it might the more readily settle.

This process succeeded for a time, but it soon became necessary to excavate the puddling over the open joint, as low down as we could, and then with a heavy piece of sheet-piling, used as a ram, to force the puddling down. This succeeded also for a time; but as the excavation of the mud advanced, and the leaks forced their way under the "montants" piles, more effectual means were required, and the puddling was therefore excavated from 15 to 20 feet in length, over the leak, to a depth of 8 or 10 feet; a bank being left on the outside to keep out the tides. By keeping the pumps in motion, the water inside could now always be kept down within certain limits. A smooth pile, 8 or 10 inches in diameter, was then selected and driven through the puddling to the cavity underneath; the pile was then drawn, (the clay being so stiff that the aperture formed by it remained open,) and a communication was thus opened with the leak. The period of low water was seized upon, the pumps were turned upon the puddling, and a head of water was created over the opening made by the pile. Dry, powdered clay, previously prepared, was thrown in, and, being carried down by the force of the water, it filled the cavity below, and stopped the leak.

This expedient, like the others, had its limits; for, as the excavation of mud went on, the weight of water increased from without, and it became impossible to create a sufficient head of water to counteract it.

The method of driving piles was nevertheless continued, and they were known to have pierced the leak, by the water following them when drawn. The pumps were not used, but fine clay was poured down the opening until it was filled; a pile, square at the lower end, was then inserted, to force down the dry, fine clay. This was a very slow operation, but still it succeeded.

At first these piles were driven by a heavy block of timber, worked by hand over a sheave, suspended at the end of a crane; but the leaks were of such frequent occurrence, and it being apparent also that the whole of the puddling must be packed down in this way, a light pile-driver was constructed, especially for that use.

By constantly persevering in this method we finally succeeded in reaching the rock at one end of the dam, but not in time to clear it off and commence the masonry before the winter set in.

Early in the season preparations had been made for constructing a dam for the southern abutment, and it was commenced on the 1st of July, with such modifications and improvements as the experience gained on the first and second dams suggested.

The abutment being 34 feet long and 21 feet thick, with circular wing-walls 13 feet average thickness at the base, and 69 feet long, the dam was formed so as to inclose the area of the abutment, and leave a small space between the interior of the dam and the masonry. (See plate 4.)

The interior framing of the dam, as low down as the surface of the mud, was built upon the shore, and was then launched and floated to its position. The framing was as follows: the lower stringers to rest upon the mud; timbers 18 inches square were laid upon the trace, and simply halved and bolted together at the angles; upon the inside of these, posts 18 inches square and 16 feet 6 inches long were erected, 8 feet 6 inches apart from center to center, in the main body of the dam, and in the wings they were arranged to divide the space uniformly.

These posts were notched on the stringers, and against the posts were placed the shores, 15 inches square timber. The shores were cut beveling at the ends, and corresponding notches were cut in the posts, with oak wedges underneath the shores, for the purpose of relieving them when required to be taken out.

The posts and shores were secured to the stringers by two iron straps, with an eye in one end, let into the stringer by a mortise, through which a bolt was dropped by a hole bored from the top. The opposite ends of the iron straps were secured to the shores by a gib and key passing through a mortise in the shores and straps

Above these, 4 feet 6 inches in the clear, was placed another set of stringers and shores, the stringers 16 inches and the shores 14 inches square, arranged and secured as those below. Nine feet above this the top tier, on a level with high water, was placed. The stringers of this tier were 13 inches square, and the shores were 12 inches square. The shores of this tier were not beveled at the ends as the others, but were set square against the posts, and secured simply by a frame-bolt passing through the stringer and post into the ends of the shore.

The ends of the dam were braced by timbers of the same dimensions as the shores in each set, let into the stringers with a bearing-joint, and secured by a bolt. The frame was then braced, to prevent its racking, by pieces of sheet-piling placed diagonally on its sides, and bolted to the posts on the inside.

The outer side of the stringers was dressed, and each set placed fair above each other.

This framing was floated to its position on the axis of the aqueduct, and was made to sink in the water by proper weights, until the lower stringers rested upon the mud. The pile-drivers were placed upon opposite sides of the frame, each with a sheet-pile suspended in the planes; and as soon as the frame was arranged in its place, the piles were dropped, and driven and bolted to the stringers, thus securing the frame in its position. The sheet-piles were then driven all around, resting against the faces of the stringers, without "montants" or other guides, and every pile was driven to the rock. With respect to the outer rows of piles of this dam, they resemble those heretofore constructed, with the exception of the "montants," which were dispensed with, and in their stead temporary guides were used, and withdrawn as the sheet-piling progressed. Every oak and sheet pile in this row was also driven to the rock. The stringers and ties were all of white oak. The stringers were butted together, and the joints were covered by short pieces that embraced, each, five to seven oak piles. The ties were placed at every other oak pile. Before we enumerate the advantages of this *new* mode of construction, it may be permitted to point out what we consider defects in the old. In the first place, then, the interior row of oak piles used in dams Nos. 1 and 2 were found to be not only *useless* but *pernicious*, inasmuch as they cannot be procured of precisely similar diameters, and they could not be worked to *pattern* without great expense; and even then it was nearly impossible to drive them in so great a depth so accurately as to preserve the alignment all the way down.

Secondly. The irregularity of the oak piles then affected the sheet-piling, because the guides by which they are driven rested against the oak piles; the sheet-piles were thus often made to pass each other and leave open joints.

In dam No. 1 a badly driven oak pile, which projected very much into the dam, was cut out, and others that were out of line required to be notched, and, of course, much weakened, in order to place the stringers for the shores in line; nevertheless, the stability of the dam did not appear to be at all affected. Hence the opinion that these oak piles were both useless and embarrassing.

Thirdly. The montant-piles were found to have caused nearly all the leakage in dams Nos. 1 and 2. It was under them that the sand and gravel and water found their way into the dams.

Fourthly. The water in the first dams required to be pumped out to certain depths before a tier of shores could be placed; and when it was pumped out, the space between the oak and sheet piles allowed the sheet-piles to spring inwards, by the weight of the puddling, before it was possible to block in between them all around.

Another objection is, that the length of each stringer and shore has to be determined, framed, and fitted before it can be keyed-up; and this not for one tier only, but, in fact, every tier has to be so framed and fitted inside of the dam, an operation involving great inconvenience and delay. All these objections (and they are serious ones) are believed to be obviated in the mode of construction ultimately adopted. In it, every pile being driven to the rock, the only apprehension of leakage will arise from open joints of the sheet-piling; and if this should occur, (and it may, by the point of a pile being turned by an obstacle in driving,) the joints can be sufficiently closed by driving another pile to cover the opening, there being no montant or sash-pile to prevent it.

The inner row of sheet-piles being in immediate contact with or resting against the stringers of the shores, there can be no possibility of their springing with the weight of the puddling or pressure of the water, without crushing the shores.

And the shores themselves are made to act as ties, by means of the iron straps at their ends, and prevent the dam from spreading from the weight of the puddling and of the water in the dam as the tide ebbs, (the dam being tight, and having been filled by high water flowing over the top, or other causes.)

The dam as soon as it is completed can be pumped down to the surface of the mud, as all the shores required above the mud form part of the frame-work of the dam. Again, the shores and stringers required below the surface of the mud can be framed and fitted upon the land, inasmuch as we may assume the interior of the dam to be some definite figure, and its dimensions therefore known. In this manner has the dam for the southern abutment of the aqueduct been constructed, and it is a matter of great regret that it could not have been altogether completed and tested this season; but a force of mechanics sufficient for the purpose could not be obtained. Another extensive work in the vicinity being in progress at the same time, the demand for labor was very great. Previous to the commencement of this dam, a saw-mill had been contrived by Mr. B. F. Miller, the master-carpenter and superintendent of the work, an experienced millwright, and a man of great mechanical ingenuity. It was erected upon the float of one of the steam-scows, and was driven by the steam-engine at work upon the pumps.

This machine not only saved great expense to the company, but it enabled us to execute much more accurate work, that could not otherwise have been done. By this machine two saws trimmed at once both edges of a sheet-pile perfectly parallel, and enabled us to obtain joints more perfect than we could either by hewing or planing. There was attached to the machine a circular saw also, which was used for cutting out oak wedges and other small pieces.

The work done by the circular saw alone would nearly have covered the entire cost of the mill in one season. With it one carpenter and one laborer performed in one day the work which last year required from ten to twelve carpenters.

On the 7th of December the winter set in, and the campaign of 1835 closed.

Lieutenant M. C. Ewing, of the Fourth Regiment of Artillery, has served with me during the whole period as my assistant, in whose zeal and industry, combined with his theoretical attainments and practical experience, I have great confidence.

Lieutenant R. S. Smith, of the Second Regiment of Infantry, was temporarily attached to my party, and rendered very efficient service.

Accompanying this report are detailed drawings of all the machinery used, and of the work itself, and also detailed statements of the expenditures of each year, including the cost of machinery, &c.

All of which is respectfully submitted by your very obedient servant,

WM. TURNBULL,
Captain and Assistant, Topographical Engineers.

Lieutenant-Colonel ABERT,
Topographical Bureau.

Extracts from the journal of 1836.

The work did not sustain any injury by the ice or other causes during the winter, and, on the 22d of March, the operations were resumed by boating clay to replace a settlement in the puddling of dam No. 1, repairing the steam-engines, and driving sheet-piles of the abutment coffer-dam.

26th.—The puddling of dam No. 1 was brought to its original height, and we commenced filling holes on the outside, formed by the sand being drawn into the dam through the leaks.

April 18.—The steam-engines being repaired, and all things in readiness, an attempt was made to empty dam No. 1, but without success; the water was lowered, however, sufficiently to discover the leak in the northwest corner underneath the puddling. The puddling was removed at top, and the usual mode of driving a pile through to the leak was followed, and was attended with success. On the 21st a difference of 15 inches was observed between the water in and outside of the dam; this difference increased daily. On the 25th the water ebbed and flowed but 2½ inches in the dam; and on the 26th the dam was emptied of water in six and a quarter hours, and was very tight, one pump being sufficient to keep it free. There was some difficulty in procuring laborers to go below, to excavate the sand, &c., which had washed in, and it was not until the 28th that two tubs, raising sand, were at work. On the 29th a small leak opened in the southwest corner, which caused some alarm at first, but it did not increase beyond the capacity of the pumps, and the next day the leak diminished.

Sunday, May 1.—The dam was in fine order, and nearly all of the last incursion of sand and gravel was removed; the rock at the southwest corner was 3 feet above the water, and the prospect of success was quite flattering; but that night at 11 o'clock another and a very sudden incursion took place, which filled the dam in a few minutes. The puddling settled, and the usual mode of stopping the leak, by filling up the cavity underneath the puddling, was resorted to. On the 4th there was a difference in the level of the water inside and outside of the dam of 33½ inches; the water inside ebbing and flowing with the tide but 2¼ inches, showing that the communication was stopped. The operation of driving a pile through the puddling, with a view of compressing it as much as possible, was continued until midnight Sunday, the 8th, when the dam was emptied of water before sunrise of the 9th. The excavation was continued during the 9th, but the dam filled again at night. The pile was again resorted to, and persevered in until Sunday, the 15th, when the difference of level of the water inside and outside was 27 inches; the change inside but 1 inch in 24 hours. The dam was pumped out before sunrise of the 16th; very little sand had been washed in, and the excavation was resumed with a fair prospect of soon clearing off the rock. On the 17th the excavation was continued, and the rock was laid bare for some distance from each end of the dam; the pumps were lowered until they rested upon the rock; soundings were made toward the center of the dam, and a depression in the rock was found to exist; the deepest sounding of which was but 2 feet, and which was covered with compact gravel. As it would be impossible to drain this depression in the rock, the pumps being now at their lowest, even if the gravel was removed, and a small leak being discovered in the south side, which made us fear another incursion of sand, &c., it was determined to allow the dam to fill with water, to remove the windlasses, to lay the railways, put up the derrick, and to commence the masonry. The dam filled in 4½ hours, and, as there were indications of its not being tight, the pile was again resorted to, and continued until the preparations for laying stone were made, and a force of masons collected. On the 22d the dam appeared very tight, and everything being in readiness for lowering stone into the dam, it was pumped out during the night. At 9 o'clock on the 23d a leak opened, and increased so rapidly that no stone could be laid; the dam filled in the course of the day. On removing the puddling over the leak, a large cavity in the puddling was discovered, which, being filled with clay, the communication was partially stopped; driving the pile through the puddling was continued until the 25th, when the dam appeared very tight, and it was pumped out during the night, and the masonry was commenced on the 26th; and notwithstanding the weather was very stormy, great progress was made. Several very large stones were laid until 4 o'clock, when a leak of the most appalling nature opened at the southwest corner, and filled the dam in 12 minutes. The masons and their attendants had barely time to escape. The puddling over the leak settled 4 feet below high-water mark, and the sand around the corner was drawn into the dam, forming a cavity on the outside from 5 to 6 feet deep. The outer row of piles settled with the puddling, separating entirely from the ties at top. The dam being considered in some danger, every exertion was made to secure it by passing long screw-bolts through the stringers of both rows of piles, to keep them together, and throwing in clay to fill the cavity formed on the outside, and to replace the puddling.

The weather was extremely bad, but the men were induced to remain at their work, and on Sunday, the 29th, the tide was shut out; after which the water inside varied but 3½ inches, and it was ordered that the dam should be pumped out during the night. Owing to the failure of one of the steam-engines, the dam was not emptied until 10 o'clock on the 30th, at which time the derrick, with a large tub, was used for hoisting out sand, &c., which had washed in and accumulated to the height of 6 feet over the masonry laid on the 26th. At 1 o'clock a leak in the southeast corner increased very much; and soon after the pumping was suspended, the puddling at that corner settled 2 feet, and immediate measures were taken to replace it; but the storm increasing, the laborers left off work.

On the 31st, the storm continuing, the laborers refused to go to work. The river evidently rising, made it necessary to secure everything afloat about the dams. The superintendents and mechanics were employed in securing the scows, timber, &c., but, the force being so small, and the current in the river so rapid, it was impossible to remove the steam-engines from the dam. They were secured as well as possible at the dams.

June 2.—The river had risen 5 feet 7 inches above ordinary high water—a height not known here for several years. One of the steam-engines was swept from the dam and carried down the river below Mason's Island, where it was secured by a few men kept on board in case of accident.

The dams were several feet under water, and so rapid was the current that great apprehensions were entertained for their safety.

11*th*.—The freshet had so far subsided as to enable us to make a correct estimate of the damage sustained. The puddling of dam No. 1 was washed out several places to the depth of 2 and 3 feet; at the southwest corner it was washed out to the depth of 9 feet below its original surface, but none of the timbers were displaced. Soundings were taken between the dams, and between dam No. 1 and pier No. 1, and it was ascertained that nearly the entire deposit between them had been swept out; the soundings varied from 24 to 32 feet, where there was originally but 18 feet of water, and at the up-stream corners of dam No. 1 the rock was entirely bare. It was a matter of great surprise how dam No. 1 was sustained; the outer row of piles had not been driven to the rock, and the deposit was entirely swept from their feet, except at the down-stream end, where it was sheltered. The sheet-piles of the northern face of the abutment were all displaced about 20 feet in length; at the eastern or down-stream end of this was swept off; the remainder of the sheet-piles floated up, and were caught by the *montants*. The oak piles were all swinging by the bolts which attached them to the stringers; a small portion of the causeway, which had been thrown in advance to form a road to the abutment-dam, was swept away. Dam No. 1 being in momentary danger of falling to pieces by the puddling settling and forcing out the outer row of piles, screw-bolts were passed through the stringer of each row, to keep them together at top, and clay was thrown in to replace the original deposit and prevent their spreading at bottom. By these means the dam was preserved.

25*th*.—A sufficient quantity of clay having been thrown outside to sustain the outer row of piles of dam No. 1, clay was thrown between the rows to replace the puddling which had been washed out; but the work was again arrested on the 26th and 27th by incessant rain and the river rising. On the 28th the river was 3 feet 5 inches above ordinary high-water mark, which is much higher than the usual freshets—higher, at least, than any observed here since the commencement of this work; but, as it had been asserted by those unfriendly to the work that an ordinary freshet was sufficient to cause the sweeping out of the bed of the river, which occurred near the work in the early part of this month, constant watch was kept by frequent soundings during the freshet on the clay thrown outside for the preservation of the dam, and not the least change was observed.

29*th.*—The freshet subsided, and the soundings were repeated with great care, to ascertain if any clay had been swept away; none was perceptible, except a very small quantity removed from around the up-stream corner, where the current was most rapid. Scowing clay, to replace the puddling, was resumed.

30*th.*—The puddling was so far replaced that the tide was shut out for three hours, during which time the water in the dam did not vary, plainly showing that the dam was tight.

The puddling was entirely replaced on July 4, and the dam was pumped out; but the pumps being greatly out of order, it was impossible to keep down the water low enough to continue the excavation; and on the evening of the 5th the dam filled again through a leak in the southeast corner.

The usual mode of forcing down the puddling over the leak, by driving a pile through it, was followed until the 11th, when, the dam being apparently tight, the pumps were tried again, but without success; they could not free the dam of water.

On the 14th the pumps were tried again, and the dam was emptied in nine hours. The leak in the southeast corner still existed; but in a few minutes, however, it diminished very much, and two pumps drained the dam entirely; but in the evening, when the flood-tide made, the leak increased and filled the dam.

On the 20th the dam was pumped out again, but soon filled.

August 4.—Another attempt was made to free the dam, but with no better success than heretofore; it was emptied, but filled again immediately.

It had been our impression for some time past that some more effectual mode of tightening dam No. 1 than the one heretofore followed must be adopted, or the dam must fail of its intended object. Nothing but the length of time it would require to make the alteration or addition to the dam, and the possibility of succeeding by perseverance in the mode already pursued, deterred us from proposing it before; but as all hopes of succeeding by that mode were now abandoned, and as it was impossible that the dam in its present crippled condition could withstand the shock of another winter, there was no alternative but to adopt the best means within our control to save it from destruction, and endeavor to raise the masonry in it above water before the winter set in.

Three plans suggested themselves:

1st. To drive a third row of piles outside, down to the rock, and to fill the space between with clay.

2d. To draw the outer row of piles, and suffer the puddling to slope down into the water and fill up at top, against the inner row of piles, until the tides were shut out.

3d. To form a bank of clay against the outer row of piles up to low-water mark; this, it was believed, by spreading itself some distance from the dam, would cover all passages underneath the old puddling and tighten the dam; and being the most simple and easiest executed of the three, was adopted and commenced on the 16th of August.

September 5.—The water in dam No. 1 for some days past has been nearly stagnant, and it was believed that the plan adopted had already made it tight. It was determined to try the pumps, and the dam was pumped out in eight hours; but the leaks being but partially stopped, and fearing that they might wash larger, it was thought most prudent to cease pumping and allow the dam to fill, (which it did very gradually,) and to pursue the plan of tightening it until the clay should be brought up to low-water mark. During this time the repairs of the abutment-dam were going on also. The piles of the northern face, displaced by the freshet in June, were all taken out and redriven and the puddling was filled in.

The mode of pumping followed in dams Nos. 1 and 2 being found to be very expensive, and subject to frequent interruptions by the ropes chafing and the leather cones or buckets bursting, wearing of the interior of the pumps, &c., it was determined to adopt some more permanent mode of pumping for the abutment-dam, and a plan was devised as follows: four square posts were erected on the angles of a parallelogram; on the inside of each pair of posts iron rails were fixed at a convenient height, and between which two gates, with cast-iron cross-heads, (similar to the saw-gates of a saw-mill,) were placed; immediately under these gates, and against each post, the pumps were placed, and to the gates were attached the piston-rods of the pumps, with long screws at top for the purpose of adjusting their length; two connecting-rods were attached by joints to the lower bar of each gate; the opposite ends of these rods were attached by joints, also, to the ends of two horizontal levers fixed upon a cast-iron shaft in the center, the journals of the shaft resting upon the sills of the posts; and underneath the shaft is a cast-iron arm, to the lower end of which is attached a connecting-rod, the opposite end of which is in a swinging-frame supported over the outer row of piles of the dam; and from this swinging-frame another rod connects with the crank of the steam-engine, which, when in operation, gives to the horizontal levers a tilting motion, and, by means of the connecting-rods, at their ends, a vertical motion to the gates over the pumps. Cast-iron cylinders were inserted and fixed at a proper height in the pump-stocks, (which were the same as before used,) their length proportioned to the length of strokes to be given to the piston-rods. Cast-iron boxes, or valves, fitted nicely to the cylinder, were also adopted; the lower valves were the same as heretofore used. When the pumps are lowered the piston-rods are lengthened by bars of various lengths, with square sockets at their ends. The screw at top is intended to adjust the length *nicely*, to keep the valve at its end within the iron cylinder according to the stroke. (See Plate 5.)

This machinery was completed on the 10th of October, and on the first trial worked admirably; the four pumps worked by it emptied the dam in four hours and seventeen minutes, including ten minutes stoppage for adjustment, &c. The contents of the dam were 71,050 cubic feet of water, equal to 435,394.4 gallons; the discharge per minute was therefore 1,694 gallons, or 423.5 gallons by each pump. The engine working twenty-one strokes per minute, gives 20.1 gallons for each stroke by one pump.

This trial of the pumps was made to test the tightness of the dam as well as the motion of the machinery; both proved very satisfactory. Every timber of the dam was well in place, and the joint of the sheet-piles extremely close. It will be recollected that the plan of this dam is entirely different from the two others constructed; the changes were suggested by the difficulties encountered in the others, and so far as they have been tested they are decided improvements. The windlasses for raising mud, &c., not being up, the excavation could not be begun, and the dam was suffered to fill, which it did very slowly.

On the 16th of October, the windlasses having been erected over the wing of the dam in which the pumps stand, it was determined to pump out the dam again and commence the excavation. The dam was pumped out very easily, but a sufficient number of laborers could not be procured to go on with the excavation and it was not attempted. For some time past it was observed that the water in dam No. 1 had become dark and offensive like bilge-water—an evidence of its growing tight; it was regularly measured, and its level varied only between 1 and 3 inches in twenty-four hours, according to the height of the tide.

On the 17th, the day after pumping out the abutment-dam, the water in dam No. 1 was observed to have fallen 2 feet 6 inches below its ordinary level, which could not be accounted for. It was closely watched during the day, and at low tide the water inside of dam No. 1 was 5 inches the lowest, which rendered it still more unaccountable; but there could be no other conclusion than that the water in dam No. 1 had been lowered by pumping out the abutment-dam.

To test this further, on the 18th the water, which had risen 4 feet in the abutment-dam, was again drained, and the water in dam No. 1 lowered $\frac{3}{8}$ of an inch, whilst the tide rose 2 feet 1 inch outside.

Strong hopes were now entertained that by keeping the abutment-dam empty, dam No. 1 could also be kept empty. Accordingly, on the evening of the 18th, the pumps of dam No. 1 were ordered to be set in motion. The filling in with clay around dam No. 1 prevented us from using the steam-engine on the side which worked four pumps, consequently the engine at the end, which worked but two pumps, could only be used; but notwithstanding there were frequent interruptions and but one pump at work the greater part of the night, the dam was emptied, and proved to be very tight. Marks were established upon the abutment-dam to determine if the emptying of dam No. 1 would cause a difference in the rising of the water in the abutment-dam. The result was as follows: when dam No. 1 was full, the water rose in the abutment-dam 44 inches in fifteen hours; and when dam No. 1 was empty, the water rose in the abutment-dam but 13 inches in twenty-two hours; incontestably proving that there must be a communication between the two dams, and which must be through a fissure in the rock, as the space between the dams is now covered with a very tenacious clay much deeper than the original deposit.

The excavation of dam No. 1 was resumed on the 19th with a derrick, and a large quantity of the last incursion of sand, &c., was removed. After some progress had been made in the excavation, the leak in the southwest corner, at the high point of rock, was found still to be open, but not to an extent to cause any alarm, as one pump was sufficient to keep it down. The dam continued in fine order for work; still there was frequent interruption by the steam-engines getting out of order, the pump-ropes breaking, &c.; but, notwithstanding, on the 25th the stone before laid was cleared off and the masonry at the up-stream end was resumed, and gradually extended towards the other end of the dam as the mud and sand were removed.

November 5.—The last of the mud was removed; the windlasses were taken down and a derrick put in their stead, and several very large stones were laid in the down stream end of the pier; the masonry from the up-stream end to past the center had reached the second tier of shores from the rock. Our prospects were extremely flattering, and it was hoped that all difficulties had been overcome. The dam was unusually tight all day; the pumps had been idle for three hours, without the water rising to inconvenience the masons, when at sunset the leak in the southwest corner opened suddenly and filled the dam in thirty minutes; the bank of clay around the corner settled down. The next morning the mechanics and laborers were all set to work to replace the clay, which had the effect of tightening the dam, as high water in the evening stood 28 inches higher than the water in the dam. The water in the abutment-dam, which had been at rest for several days, rose 2 feet, when dam No. 1 filled.

Monday, *November* 7.—Boating clay to the bank outside of dam No. 1 was continued, and the dam was improved by it; high water stood 3 feet above the water inside. The water in the abutment-dam continued to rise, and it was determined to pump it out at night, and observe the effect on dam No. 1.

November 8.—The abutment-dam was empty and the water in dam No. 1 had fallen 6 inches; it continued to fall during the day, and at night it had fallen 15 inches, which was 9 inches below low water. The water in the abutment-dam rose rapidly. The bank of clay outside of dam No. 1 having been brought well up, and high water standing 4 feet 2 inches above the water in the dam, it was ordered to be pumped out at night.

November 9.—Dam No. 1 free of water and in tolerable condition, for the sand washed in by the last leak was very inconsiderable, and the masonry was resumed with renewed exertions and advanced rapidly. During the day a leak was observed in the down-stream end, which caused some alarm for a time; but the puddling settled, and the pumps kept the water down.

From this time on the masonry progressed rapidly, although frequently interrupted by the pumps and steam-engines getting out of order, rain, rapid currents in the river, and high winds, which made it very difficult to get the scows with stone to the dam; and on the 26th of November the masonry had reached the first tier of shores, or within 10 feet of high-water mark. One pump was quite sufficient to keep the water below the masonry, and the work was considered quite secure from further interruption by leakage; still it required great exertions to raise the masonry above high-water mark before the severity of the winter should cut off the supply of stone. The weather was already quite cold; the river was covered with ice, but a passage was kept open to the dam, and a scow was kept running day and night through the canal to keep it open and insure the supply of stone. By extraordinary exertions the masonry was brought above high-water mark on the 8th of December, from which point it can be readily carried up to its intended height without the aid of the dam. The masonry was suspended, and our attention turned to removing the coffer-dam.

Experience in drawing the piles of dam No. 2 suggested an improvement in removing dam No. 1. It was proposed to substitute a steam-engine, instead of a winch worked by hand, for drawing the piles of dam No. 1; and a plan was advised, and put in operation on the 15th of December, which succeeded very well. It consisted simply of a stout and long lever, the end of which was raised by a treble and double purchase, the fall of which passed round a drum upon the main shaft of the steam-engine. The purchase-blocks were suspended from a single derrick, or pair of shears, which was easily moved from one end of the dam to the other; at first two sheet-piles were drawn together 2 feet 2 inches at each raising of the lever. The lever was raised three times in two minutes; but as some piles were more difficult to draw than others, great delay in drawing two at a time was encountered by breaking of the chains, &c., and but one at a time was drawn thereafter. Great progress was made in the removal of the dam at the end of the year.

It is a source of extreme regret to the engineer that greater progress in the work has not been made during the past year as was anticipated; but it is equally a source of congratulation to him to be able to say that every effort was used to overcome all difficulties within the control of human means; and that his efforts have not been successful need not be a subject of surprise if the nature of his undertaking be *properly understood.*

Respectfully submitted, by your obedient servant,

WILLIAM TURNBULL,
Captain and Assistant, Topographical Engineers.

Lieutenant-Colonel Abert,
Topographical Bureau, Washington City.

Extract from the journal of 1837.

The months of January, February, and part of March, were occupied in removing the coffer-dam of pier No. 1, the piles of which were drawn by the steam-engine in the manner heretofore described.

Early in March preparations were made for emptying the coffer-dam for the southern abutment.

On the 19th a trial was made with the pumps for one hour. Everything seemed in good order; and the water was lowered 3 feet 11 inches in that time.

On the 20th the pumping was continued; and the dam was emptied of water in 4 hours and 29 minutes, including the time consumed in pumping yesterday.

The average number of strokes of each pump per minute was 14.96; the whole quantity of water thrown out was 411,902 gallons; by each pump per minute 382.80; and by every stroke of each pump 25.58 gallons.

After working a short time one of the pumps leaked badly, and was supposed not to throw exceeding one-half of its capacity of water. The dam was very tight, one pump being more than sufficient to overcome the filtration.

The excavation of the mud was commenced in the afternoon of the same day, and was confined to the eastern wing of the dam, owing to the small force of the laborers employed. It was carried down at once to the depth at which another tier of shores was required, which was 7 feet below the original surface of the mud.

March 30.—The laborers excavating moved into the main body of the dam, and the carpenters commenced placing the shores in the wing. The pumps being lowered, as the mud was excavated from the wing, the other portion of the dam was so well drained that the laborers worked perfectly dry.

The force was now increased sufficient to the working of three tubs in raising the mud, being still greatly below that which might have been employed could laborers have been procured; this being the season for fishing, however, a sufficient number of hands could not be obtained to man the whole line of windlasses. Yet, notwithstanding, such was the facility with which they worked below, that the mud in the main body of the dam was rapidly reduced to the level of the eastern wing.

On the 9th of April the laborers moved into the western wing, when the carpenters commenced shoring the main body of the dam.

The force was now increased to four tubs, and the excavation went on rapidly. On the 15th the rock was touched in the western wing; and on the 19th the mud, &c., in the wing was entirely removed, and the shoring was commenced on the 20th.

The laborers removed to the eastern wing; soundings were taken to ascertain the depth of mud yet to be removed from that end of the dam, and there was found to be about 5 feet.

On the 21st a small leak opened in the east end of the dam, which caused some alarm, and drove the laborers into the main body; but the leak proved to be of no importance, as one pump was still sufficient to keep the water down without interruption to the excavation.

On the 29th of April the excavation of the dam was completed, the rock being bare from end to end, having been done in the short time of thirty-four working-days, with but one-third of the force that might have been employed could they have been procured.

It is needless to say anything in favor of the construction of this dam; it fulfilled our most sanguine expectations; all the changes from the former mode of construction proved to be decided improvements. They have been fully described heretofore, and drawings in detail furnished.

The modifications of the pumps and the pumping-machinery proved likewise to be great improvements, particularly on the score of economy. These have also been described before, and drawings given.

The windlasses used in raising the mud were now removed, and preparations were made for commencing the masonry.

On the 2d of May the railways for the derricks were laid, and a boat-load of stone was alongside the dam; the superintendent, also, with a small force of masons in readiness to commence the masonry, when the leak in the east end, heretofore mentioned, increased suddenly to an alarming extent, and immediately filled the dam. All efforts to contend with it were useless, as the pumps soon became choked with gravel and other matter which was forced in through the leak.

The puddling did not settle, as was anticipated; consequently the tide ebbed and flowed freely in the dam, and continued to do so until the 6th, when a difference of 12½ inches was observed in the level of the water inside and outside of the dam at high water.

On the 7th a trial was made with the pumps, but without success; the water in the dam was lowered but 3 feet 6 inches in 6 hours; after which time the leak gained upon the pumps. As the puddling did not settle, recourse was had to the old method of driving a pile through the puddling, which was successful; the leak was pierced on the first trial; clay was forced down the opening made by the pile; and on the 9th the difference of level between the water outside and inside of the dam, at high water, was 31 inches, the ebb and flow in the dam being only 3 inches. Forcing clay into the cavity underneath the puddling was persevered in until the 15th, when the ebb and flow of water in the dam was 1¼ inch. The pumps were tried again with every prospect of emptying the dam; the water was lowering rapidly, when an accident happened to the machinery which caused a suspension of the pumping until midnight, when it was resumed.

At sunrise of the 16th the water was down to the lower tier of shores, when the leak opened again and filled the dam.

The same mode of stopping the leak was followed, with the addition of a quantity of hay mixed with the clay, and forced into the cavity beneath. This had a very good effect; the hay was afterward seen drawn into the open joints, about the feet of the piles.

The dam was gradually made tight by these means, and on the 21st the ebb and flow of water inside was but 2 inches. The pumps were put in motion, and the water was lowered about 10 feet very slowly; the leak was still perceptible. The pumps, however, were kept at work, and the water was lowered 25 feet, when the leak increased with great force and filled the dam in 15 minutes. The rush of water was so great, and formed so great a cavity beneath the puddling, that it settled about 12 inches across the east end of the dam, but not sufficiently to make it perfectly tight. The old method of stopping the leak was persevered in, and on the 25th another effort was made to free the dam of water, with success.

At sunset the water was 1 foot below the lower tier of shores, and no leak was perceptible. The next day (26th) the dam was entirely drained of water, and one pump was sufficient to keep it so.

But comparatively a small quantity of sand had accumulated in the east end of the dam, and was no detriment to commencing the masonry in the west end where the rock was much the highest. The machinery for laying stone was in readiness, and the masons were assembling for work on the 27th; but to our great dismay, just before daylight a leak opened in the west end, which filled the dam in 30 minutes. A very small thread of a stream had been observed exactly in the corner joint, for some time past, but no apprehension was felt on account of it. It had, however, been gradually washing in the sand and forming a cavity beneath the puddling, until it formed a connection with the outside; when the incursion took place the puddling settled immediately, and the dam became tight.

On the 30th the variation of the water inside was but half an inch; and on the 31st the dam was emptied by three pumps before sunset, one being disabled by a block of wood getting into the chamber.

June 1.—The dam was in good order, and the masonry was commenced and continued without interruption until the 7th, when at night the dam filled from a leak in the north side of the west wing; the puddling settled. On the 9th, the dam being apparently tight, the pumps were tried, but without effect; the water was lowered about 11 feet, when the leak opened and filled the dam.

On the 13th the dam was again made tight by the usual method of forcing hay and clay into the cavity beneath the puddling, and the pumps were put in motion at night; the water was lowered very rapidly, but in the morning (14th) an accident happened to the machinery which caused a suspension of the pumping for 4 hours, during which time the water in the dam rose but 15 inches; before sunset, however, the dam was entirely drained of water. This was the last interruption by leaks in this dam.

The small quantity of sand, &c., which had been washed in at the upper end of the dam was soon cleared off, and that which accumulated in the east end was hoisted out by a windlass left at that end for the purpose.

The masonry now advanced with activity until it reached its intended height, 28 feet above high-water mark.

The experience of constructing three dams has proved that the mud, &c., between the rows of piles must be washed into the dam, and the puddling take its place, before the dam can be made tight; or what, in my opinion, would be better, that the mud be excavated before the puddling is thrown in. But this would require expensive machinery for the purpose.

It will be recollected that all the leaks which occurred in the abutment-dam were at the ends of the dam. When this dam was in an unfinished state, in the month of June, 1836, (that is, before the puddling was put in,) an extraordinary freshet in the river occurred, an account of which has been before given, which swept out the deposit between the abutment-dam of pier No. 1, leaving the rock bare, and taking with it dam and the outer rows of oak and sheet piles on the northern or principal face of the abutment-dam. Before these piles could be replaced, it was necessary, of course, that there should be something to sustain the feet of them; and, to attain this object, a bridge was constructed across the main body of the dam, and connecting it with the causeway; clay was then carted to the inner row of piles, and emptied into the river.

When this clay was raised to a sufficient height, the piles of the outer row were again driven, and the puddling was raised to its proper height, which, resting upon the rock, made that side of the dam perfectly tight; no leaks ever occurred there.

The wings of the dam being flared, escaped the effects of the freshet; and the mud and sand between the rows of piles remained there, and the puddling was thrown upon it.

On the south side of the dam there was but one row of sheet-piles; the clay of the causeway was extended out to it, and formed the puddling of that side, which rendered it secure, probably from its great weight. No leaks ever occurred on that side.

From the construction of this dam it was believed that the puddling would have settled immediately upon a leak taking place, no montants having been used in the inner row. This not being the case, however, can only be accounted for by the clay having formed itself into so compact a body, from the length of time which had elapsed since it was placed there, as to sustain itself against the side of the dam, in the event of a small cavity being formed beneath it. The sheet-piles being all driven to the rock, and the joints well closed, except very near the rock, where the piles coming in contact with it glanced a little, a sufficient quantity of sand could not be washed in by a single leak, neither so great a rush of water as to create a cavity large enough to break the clay above it.

On the 26th of May we commenced preparing the timbers for the framing of the coffer-dam for pier No. 3, being an abutment-pier; but a very small force of carpenters only could be procured for this purpose. It was very doubtful whether we could, even with a good force, complete another dam, empty it, and get the masonry up this season; still, it was determined to make the attempt. The frame of the dam was not launched until the 29th of July; the top stringers and shores were put on after launching.

In the mean time the oak piles for the outer row of the dam were driven, and on the 9th of August the framing was floated within the inclosure made by the oak piles.

A difficulty here presented itself in sinking the frame to its position in the mud, this dam being greater in elevation than either of the others by reason of the increased depth of water, making an additional set of shores and stringers necessary, the lower shores and stringers giving additional bouyancy to the whole mass. The bottom of the river or surface of the mud being very uneven, it was a difficult matter to establish all parts of the framing on the same level, as upon a fall of the tide the whole grounded, and, of course, assumed an inclination corresponding with that of the bottom; and when again set afloat by a rise of tide, the smallest weight placed upon the top being sufficient to throw the whole out of equilibrium.

Recourse was now had, at low water, to the placing of scows to act as floats under the upper course of shores, blocks being inserted between the deck of the scow and the under side of the shores. This proved sufficient to keep the whole afloat until such time as a sheet-pile could be driven on the south or deeper side of the framing; to this pile, then, the south side of the frame was bolted when the other side had attained its resting-place upon the mud, and thus the whole was permanently fixed upon the same level. In order to insure this, however, other sheet-piles were driven and bolted to the frame. This occupied our time until the 15th, when the driving of the sheet-piles of the inner was commenced and prosecuted with great activity.

On the 24th of August the inner row of sheet-piles was completed, and on the 5th of September the outer row of sheet-piles was so far advanced, and the ties being in place, that the puddling was commenced. There being so little support for the feet of the piles of the south outer row, (the mud varying in depth from only 18 inches to 4 feet 6 inches,) that it was deemed proper to give additional strength to that side for fear that the puddling would press it out.

One plan for doing this was to construct a frame-work of large timbers between the outer row of oak piles and the adjacent piers, touching both, and sinking it several feet below low-water mark.

Another plan was to place an additional oak stringer on the oak piles, as low down as possible, and secure it by means of iron bolts to the interior; this, it was thought, would be sufficient, and accordingly a very low tide was selected, and the stringer was put on and secured to each post of the interior framing by screw-bolts of 2-inch iron.

This answered the purpose, although the piles did spread at the foot somewhat, with the great weight of the puddling, and drew the screw-nuts entirely through the post in some instances.

The bolts, too, were the cause of serious trouble afterwards by permitting the water to find its way through the puddling into the dam underneath them.

The great weight of the clay, which caused the spreading of the outer row of piles, drew with it (by means of the ties connecting the two rows) the top course of stringers of the interior framing, drawing out the frame-bolts which secured them to the posts and shores, and caused an opening of the dam at top.

This was easily remedied by putting on additional ties, and notching them on to the shores, and securing them there by iron bolts. By these means the shores were converted into long ties, binding the four rows of piles of the sides each with the other, and effectually prevented any further spreading.

On the 12th of September the driving of the outer row of sheet-piles was completed; and a bridge having been constructed over one wing of the abutment-dam, to facilitate the carting of clay to the boats, the puddling was carried on with great activity, and was completed on the 23d of September.

In the mean time the pumps and pumping machinery were brought from the abutment-dam and placed upon this. The windlasses for hoisting out the mud were also placed, and everything was in readiness for emptying this dam by the 1st of October; accordingly, on that day, the dam was pumped out in five hours and fourteen minutes.

A small leak was discovered on the south side, where there was the least mud, which soon increased and filled the dam in twenty-five minutes; the puddling settled immediately.

It was replaced on the 2d, and the dam was pumped out again on the 3d; but it filled again at night by a leak in the northwest corner.

It was pumped out again on the 5th in four hours and forty-five minutes. The number of gallons of water thrown out was 365,000; the average number of strokes of the pumps per minute was 13.91; and the number of gallons discharged per minute was 362.4.

The excavation was commenced in the afternoon. On the 6th the dam was in fine order, and the excavation was continued with great activity with five tubs; but at sunset a leak opened near the pumps which filled the dam that night.

It would be but a continued repetition of details to describe all the leaks which occurred in this dam. Suffice it to say, that it filled and was emptied fourteen times between the 1st and 29th of October, when the masonry was begun at the up-stream end of the dam on the bare rock.

The dam filled three times more between the 29th of October and the 9th of November.

In these last leaks recourse was had to driving a pile through the puddling as before; with the leaks previous, however, this was unnecessary, as the puddling settled in every instance until it had gone down the entire circuit of the dam.

The masonry was now carried on without interruption and with great rapidity until it had reached 3 feet in height above high-water mark, which was as high as it could be raised by the machinery then used, and which was accomplished by the 5th of December, when it was suspended, and the machinery and preparations were made for removing the dam.

The weather being still favorable, the masons were transferred to pier No. 1, which had been left last year on a level with high-water mark. It was carried up to its proper height by the 19th of December.

The arrangements for drawing the piles of coffer-dam No. 3 were completed on the 16th of December, and the drawing was commenced on that day.

The account heretofore given of the mode of drawing the piles being very imperfect, and some changes having been made in the arrangements for drawing, it may be well here to give a more perfect description of the manner in which they were drawn. The facility with which they were drawn was owing as much to the men having become more expert in the use of the machinery as anything else.

The machinery for drawing the piles consisted of a lever of the second order, 43 feet long and 16 inches square, of Carolina pine, one end resting upon the fulcrum outside of the row of piles to be drawn; the other end was suspended by a large tackle (three sheaves in each block) under a derrick, or shears, standing upon the dam.

The derrick was formed by two timbers, 11 by 6 inches, simply halved and bolted together at top, the feet being tenoned into a sill 20 feet long and 15 inches square.

The derrick was high enough to allow the blocks to separate 16 feet; it was guyed from the top to either end of the dam, and could be moved as occasion required.

A snatch-block was fixed at the foot of the derrick, through which the fall (which was of 6-inch white hemp) was passed to a drum 3 feet in diameter, attached to the steam-engine stationed at the down-stream end of the dam.

A stout chain was fixed upon the lever, directly over the pile to be drawn, at a distance of from 5 to 25 feet from the fulcrum, as occasion required; the chain forming a noose around the pile.

The steam-engine being put in motion, wound the fall upon the drum, and raised the end of the lever from 12 to 16 feet, which drew with it the pile from 2 to 11 feet in height, ccording to the distance the chain was from the fulcrum.

The steam-engine was worked by hand backwards and forwards alternately; when moved backwards, the weight of the lever overhauled the fall and lowered itself; the chain was slipped down the pile as the lever descended, when the lever was immediately raised again. The lever could be raised three times in two minutes, which was sometimes sufficient to draw a pile so that it could be hoisted out by other means.

Five hundred and ninety piles of dam No. 3 were drawn in eight and three-fourths days. The number of piles drawn in a day varied according to circumstances; the greatest number drawn in one day was fifty-three; the least number was fifteen; and the average number drawn per day was thirty-one.

The number of laborers employed in drawing piles was but five—one stationed upon the steam-engine at the drum, two upon a staging to arrange the chain around the pile, and two above on the dam to attend to moving the lever, &c., and one superintendent.

Drawings exhibiting the present state of the work will accompany this report.

All of which is respectfully submitted, by your obedient servant,

WM. TURNBULL,
Major and Topographical Engineer.

Lieutenant-Colonel J. J. Abert,
Topographical Bureau, Washington City.

POTOMAC AQUEDUCT, *December* 31, 1838.

SIR: In reporting to you the progress of the work under my direction during the past year, I have great satisfaction in stating that it has been much more successful than in any previous year since its commencement.

At the general meeting of the stockholders in the month of May, 1837, the idea of letting the work by contract having been abandoned, and they having ordered it to be continued, as heretofore, by day's work, enabled us to make contracts for the supply of timber and all other materials in time to make use of them during the winter; and the frames for the coffer-dams were constructed during that period, so that, in the month of March of the present year, the work was as far advanced as it ever had been in the month of July of any previous year. The experience of past years also enabled us to suggest improvements in the machinery, dams, &c. No material changes, however, were made in the coffer-dams, but the plan so successfully used for the southern abutment and pier No. 3 was followed.

The mode of throwing the clay for the puddling between the rows of piles, upon the mud, &c., forming the bottom of the rivers, proved a source of serious inconvenience; as when the dam was emptied of water, and the excavation of the mud had progressed a little way, the column of water on the outside would find its way down the piles and underneath the puddling, and force with it the mud, &c., into the dam, through open joints in the sheet-piling. It often occurred that the rush of water was so great as to carry with it the mud on the outside of the dam, forming cavities all around it. In some instances the clay would settle immediately over the leak, and, of course, stop it; but more frequently it had to be forced down, which was a tedious operation and attended with great delay, as leaks were of every-day occurrence, until the clay reached the rock, when the dams invariably became tight. To obviate this, it was suggested to excavate the mud between the rows of piles previous to throwing in the puddling, and a machine was constructed for the purpose. It was upon the usual plan for such machines, but made extremely light, that it might be moved with facility around the dams; and was simply an endless chain, with very small buckets, containing only about a cubic foot, passing around drums supported by a light frame upon wheels, which traveled upon an iron railway and was worked by a steam-engine, which, also, by means of a tackle, hooked to the carriage and the end of the dam; the fall passing around a drum on the main shaft of the machine, moved it gradually forward as it excavated, its progress being regulated by the man attending the fall; and by a similar tackle on the opposite side of the machine it was moved back to the commencement of the cut.

The machine was first placed touching the inner row of sheet-piles, and a trench from 3 to 4 feet in width was excavated to the rock, when the clay puddling was immediately thrown in, and made to fall directly against the inner row of sheet-piles, by an inclined platform, and to fill the trench which had been excavated.

When one side of the dam was excavated, the machine, being lightened of the chain and buckets, was lifted by a crane around to the end, and so around the dam. The mud excavated was discharged by an inclined trough into a scow alongside of the dam.

The machine was first used upon the coffer-dam for pier No. 4, and when the dam was emptied of water it proved extremely tight; but when the excavation of the mud had nearly reached the rock, a leak opened in the down-stream end of the dam, which caused a great deal of trouble and detention. At first the clay settled over the leak and stopped it; but eventually the clay had to be forced down with a pile, as heretofore, and even this was but of temporary effect. The dam was emptied and filled twenty-two times from this leak *and others*. It was evident, therefore, that the leak was through a fissure in the rock, which could not be reached by the clay, and that something more effectual must be resorted to to stop it.

It should be remarked that in placing the frame of this dam we were governed by the facts developed in the previous ones—that the rock had a dip to the east, and the usual space for the pumps was allowed for at that end; but the driving of the sheet-piles around the frame showed a depression or cavity in the rock at the west or up-stream end of the dam, so that we were necessarily compelled to place the pumps there. This gave us the more space for operations upon the leak at the other end of the dam.

All the means usually followed for stopping leaks having proved ineffectual, it was determined now to drive another row of sheet-piles across the east end of the dam, and touching the first range of shores—say 16 feet from the end; to draw the inner row of piles of that end, and to allow the puddling to fall against the row last driven; which, after filling up the puddling above high-water mark, effectually stopped the leak; and the masonry was then carried up without further interruption.

The dam for the next pier having, in the mean time, been completed, the pumps, &c., as soon as they could be spared from No. 4, were transferred to dam No. 5.

This dam proved extremely tight; the water was thrown out very rapidly, (the details of which will be seen in the journal,) and the mud was excavated in an almost incredibly short time.

The masonry had attained the height of 12 feet above the rock before a leak occurred.

A very small stream in the west end of the dam had been gradually washing in sand, &c., until it eventually wore a passage large enough to fill the dam. It did not prove of much consequence, however, and did not retard the work more than eighteen hours; the puddling settled over the leak, and stopped it.

After replacing the puddling and raising the pumps above the sand that had been washed in, the dam was emptied again, and the masonry was resumed. This was the only interruption, from leaks or other causes, that occurred in this dam.

So much time having been consumed in emptying dam No. 4, it was determined not to place another dam this year, as was intended, although the frame, &c., was in readiness; the season for work being so far advanced that there was but barely time to empty another dam and get up the masonry before the winter set in, supposing that no detention from leaks and other causes should occur. But as this was rather too much to expect, it was therefore abandoned as being too hazardous to risk its being exposed to the breaking up of the ice, with a spring freshet, should we not succeed.

The force was therefore employed in removing dams Nos. 4 and 5, and which was accomplished before the end of the year.

Pier No. 3, which had been left last year on a level with the water, was carried up to its full height this year.

A great saving of time and labor was secured by substituting horse-power instead of the winch worked by men, for hoisting stone upon the piers, when above the dams.

The horse pile-drivers were used for this purpose, simply by fixing a bevel-wheel, which was cast in two pieces for the purpose, around the shaft of the windlass; another bevel-wheel at right angles, underneath the deck of the scow, the shaft of which, passing under the deck, projected beyond the side of the scow. Upon the end of this shaft was fixed a drum 2 feet in diameter, which wound up the fall of the tackle hoisting the stone. A small platform was erected over the side of the scow, upon which the men stood who managed the fall. This addition to the drivers does not interfere at all with driving piles.

During the summer and fall, as carpenters could be spared, another large and substantial scow for a steam-engine, to take the place of one of those first built, (which was rotten and not trustworthy,) was completed. The steam-engine has been transferred to it. To this engine, which is used for pumping and excavating, there is attached a saw-mill with two saws for edging sheet-piles, &c. There is also a spacious workshop in which there is a turning-lathe, circular saw, &c., and which is found to be of great convenience.

A drawing which accompanies this report exhibits the present condition of the work, viz: the southern abutment and five piers finished.

The work did not sustain any injury during the last winter, and the campaign opened on the 29th of March.

The annexed extracts from the journal kept at the work will give the operations more in detail.

All of which is respectfully submitted, by your obedient servant,

WM. TURNBULL,
Major Topographical Engineers.

Colonel J. J. ABERT,
Chief Topographical Engineer.

POTOMAC AQUEDUCT, *December* 31, 1839.

SIR: I have the honor herewith to submit extracts from the journal of this year, kept at the work under my direction.

The operations of the past year were confined to the construction of piers Nos. 6 and 8, and that portion of the northern abutment which is upon the shore.

The coffer-dam for pier No. 6 did not vary from those for piers Nos. 3, 4, and 5. It was commenced on the 30th of March and completed on the 19th of June, and was pumped out on the 20th; the mean depth of water being 14 feet.

The excavation of the mud, the greatest depth of which was 15½ feet, was commenced on the 21st of June, and was completed on the 3d of July, when the masonry was commenced.

This dam filled with water but once, and that when the masonry was at a height of 12 feet above the rock. The leak caused but a few hours' detention, and the masonry was brought up on a level with the top of the dam on the 7th of August, and to its full height on the 6th of December.

The site of pier No. 8 being in the channel-way, where there was a depth of from 25 to 30 feet of water, and not a sufficient depth of mud to sustain the piles of a coffer-dam built in the usual way, it was considered advisable to omit pier No. 7 for the present for the purpose of allowing as great a water-way as possible in case of a freshet in the river, and to go on with No. 8, the construction of which differed materially from the other dams, and which had to depend principally upon its own weight to keep it in place.

The interior framing of this dam was arranged as in the former ones, but with five tiers of shores; opposite each post, a gain, or square notch, 2½ inches deep, was cut in each stringer to receive a guide-pile. In each guide-pile there were two mortises, each 5 feet in length, large enough to admit of their moving freely on an iron bolt 1½ inches in diameter; the first mortise was within 2 feet of the foot of the pile, and the second mortise was 3 feet above the first; around each mortise a counter-sink was cut to receive a screw-nut 9 inches long, 4 inches wide, and 1½ inch thick.

The guide-piles being placed in the notches in the stringers, two bolts were passed through each post and the mortises in the pile, near the foot of the mortise, and screwed into the nuts in the counter-sinks; these bolts secured the guide-piles against the frame, and yet permitted them to be driven easily. A plank 3 inches thick, and of the same length and breadth as the pile, was spiked firmly on the outside of the pile, covering the mortises and casing in the screw-nuts.

This arrangement of the bolts permitted them to be taken out from the inside of the frame when the dam was to be removed. Each guide-pile was sharpened wedge-shape in one direction, so that in driving it would press against the frame.

The corners of the dam were formed by bolting two piles together; these piles were fitted as the others, with mortises, &c., not let into the stringers, but fitted closely to the corners; the bolts were bent and passed through the stringers and secured with a nut underneath.

Two sets of "montants," or sash-pieces, were attached to the guide-pile for the purpose of confining the sheet-piles to the frame; the first set was 7 feet from the foot of the piles, and the second set was 8 feet 9 inches above the first. They were formed of pieces of timber 1 foot by 6 inches, the length conforming to the distance between the guide-piles, and were bolted to the guide-piles; the bolt-holes in the sash-pieces being made long, so that they could play around the bolts when the guide-piles were driven.

The frame being now divided into panels, the dimensions of every panel were laid out upon a platform, and the sheet-piles of each panel were carefully jointed and fitted together, and then numbered for its place. There was a wedge, or key-pile, in the center of each panel.

When the frame was launched, placed upon the axis of the bridge, and weighted down upon the mud, the guide-piles were driven, care being first taken to ascertain, by means of an iron rod, the exact distance to the rock, which was marked upon each pile; they were driven, by very gentle blows upon each alternately until they fitted closely upon the rock.

The heads of the corner-piles were secured by a long bolt passing through them and bent around the nearest guide-pile, which prevented their being forced out by the sheet-piles.

The sheet-piles were now inserted between the sash-pieces and the stringers, all the panels being filled before the driving was begun. The distance that each pile had to be driven was marked upon it, and the driving was carried on as follows:

A strong piece of timber was laid across the dam, resting upon the heads of opposite piles; a pile-driver was stationed at each end of the timber, and the ram of one driver rested upon the timber, whilst the driver at the opposite end made a blow; and so, passing around the dam, occasionally tightening the key-pile in each panel, which prevented a pile from rebounding when it touched the rock.

In this way, after going around the dam several times, the sheet-piles were closely fitted to the rock; the mud being shallow and very soft, the blows were of course very gentle, in some cases the weight of the ram only being sufficient to force a pile down.

It may be proper to remark here that, after the dam was emptied, in one instance only was it found that a pile did not touch the rock, and at this point a very small quantity of clay oozed into the dam.

The outer row of piles of this dam was constructed in the same manner as the former ones, secured to the inner row by ties, &c., at the top.

Relying entirely upon the closeness of the vertical joints of the inner row of piles for the tightness of the dam, the only apprehension was from leaks under foot; to guard against this, a large rope of hay, formed by weaving the hay around a small cord until it was 3 feet in diameter, was laid around the foot of the inner row of piles on the outside; this was covered with clay to a height of 10 feet against the inner row, and taking its own slope in the water between the two rows of piles.

The frame of dam No. 8 was launched on the 3d of May. Some difficulty occurred in adjusting it upon the rock, owing to the inequality of the surface; and the pile-driving was not commenced until the 24th of May; it was finished on the 25th of July.

The puddling, pumping, and clearing off the soft mud upon the rock occupied until the 25th of August, when the masonry was begun.

Notwithstanding great apprehensions were at first entertained for this dam from its peculiar position and construction, it proved to be the tightest dam that we have ever constructed. Not the slightest interruption ever occurred from leaks, but it remained perfectly tight from the day it was first emptied until the completion of the masonry, which was on the 1st of November. Dam No. 8 was entirely removed by the 17th of December.

But that we were debarred by an act of Congress from throwing clay into the open river, the outer row of piles of this dam might have been dispensed with altogether; and we are decidedly of the opinion that if the sites of all the other dams had been dredged before placing the dam, and the plan of dam No. 8 followed, a great saving of time and expense would have been the consequence.

The excavation for the foundation of that portion of the northern abutment which is upon the shore was commenced on the 1st of May. The rock lay at an average depth of 19 feet below the surface of the ground. The masonry was commenced on the 4th of June and was discontinued on the 21st of December; the pier and wing-walls having been raised to the height of the coping from which the arches spring.

The present condition of the work is as follows, viz: The southern abutment complete, with the exception of the wing-walls.

Piers Nos. 1, 2, 3, 4, 5, 6, and 8, finished. The pier and wing-wall of the northern abutment within 1 foot of the springing of the arches.

Accompanying this report are two drawings—one of the interior framing, &c., of dam No. 8 in the channel-way, and the other exhibiting the state of the work at the end of he year.

All of which is respectfully submitted, by your obedient servant,

WM. TURNBULL,
Major, Topographical Engineers.

Colonel J. J. ABERT,
Chief Topographical Engineers.

POTOMAC AQUEDUCT, *December* 31, 1840.

SIR: In reporting to you the progress of the work under my direction during the past year, I have great satisfaction in saying that it has been with the same flattering success which has attended it for the two or three years previous.

At the beginning of this year there remained but one pier, and that portion of the northern abutment which required a coffer-dam, to be constructed, both of which are now nearly finished; the northern abutment wanting only the parapet-walls, forming the trunk of the canal, to complete it.

When I reflect upon the numerous difficulties which we have overcome in the progress of the work, and recall the disheartening predictions of that numerous portion of the community who looked upon the attempt to establish foundations at so great a depth, and in a situation so very exposed and dangerous, and who did not fail to treat it as an absurdity, I cannot but congratulate myself upon having so happily succeeded; and while so doing I recollect, with a very grateful sense of what I owe them for it, the very generous confidence which the president and directors of the company always reposed in me; and I recall with pleasure and admiration the unhesitating promptness with which they always seconded me, bringing to my aid their own spirit of zealous perseverance, backed by all the disposable means of the company.

There remains now only to be proven the capacity of the piers to resist the tremendous shocks to which they are annually exposed by the breaking up of the ice; they have, however, stood one very severe trial. In the month of February last the ice, which had formed to a thickness of 16 inches, broke up with a violence which had not been witnessed for many years; and the sheet formed between the aqueduct and the little falls of the river was driven against the piers, in one mass, by a current whose velocity was six miles the hour.

The spectacle was an imposing one. The ice was forced up the ice-breakers often to a height of 10 and 12 feet above them, broke by its own weight, and passed off without the slightest injury. Not a stone was displaced; and the only damage sustained at the work was the loss of a large quantity of valuable timber.

The frame of the northern abutment coffer-dam, which had been constructed during the past winter, was launched on the 26th of March. This frame was a combination of the plans of dams Nos. 7 and 8, and was shaped to fit the bottom of the river sloping from high-water mark to the channel; the posts on the front, next the channel, being 20 feet long, and those on the rear, next the shore, were only 8 feet long. The timbers were the same used in dam No. 8. The front next the channel, and for 10 feet around the corners, on the ends, was constructed in precisely the same manner as in dam No. 8, with guide-piles, &c., there being but little mud to sustain the foot of the piles. On the side next the shore there was but one row of sheet-piles to prevent the earth from falling in when the interior of the dam was excavated. The ends of the dam were constructed as heretofore by driving the piles of both rows to the rock and tying them together at the top.

In puddling no more clay was thrown on the front next the channel than was necessary to keep the hay-rope in place against the foot of the piles.

On the ends it was brought up as usual above high-water mark. In throwing in the clay at the ends, it slid under water and forced out the foot of the piles of the outer front row opposite them; and it became necessary to drive a row of sheet-piles across the ends to prevent it.

The dam was completely finished by the 21st of May; but the first attempt to empty it failed. When the water inside had been lowered about 5½ feet, a leak sprung on the front which the pumps were not able to overcome.

The leak was soon stopped, however, by means of clay and hay, and the next day the pumping was resumed; but when the water had been reduced near 11 feet, it was discovered that the pressure on the front was so great that it was forcing the frame of the dam up the bank of the river, and that it had already moved several inches. To counteract this a set of shores was placed between the frame of the dam and the land-pier of the abutment, which effectually checked any further movement. During this operation the motion of the pumps was diminished; it was, however, soon accomplished, and the dam was empty at 8 p. m.

The excavation of the mud was begun on the 23d of May. The dam being very tight, one pump was quite sufficient to keep it free of water and allow the laborers below to work perfectly dry.

The excavation was carried on with great activity until the 26th, when it was observed that the sheet-piles were very much sprung by the pressure from without; an additional set of shores was soon put in and all made secure.

On the 30th of May the rock was entirely cleared off and the masonry was begun on the 3d of June, and was carried on very successfully and without interruption until the 11th, when the dam filled with water. This was the consequence of too great a confidence in the tightness of the dam and not keeping the pumps at work, but permitting the water to rise with the masonry.

Our experience has been, in every case, that when a dam is once empty by all means keep it so if possible; and the surest mode of attaining this most desirable object is the pressure from without, which keeps the dam compact; but allow the water to rise inside and approach an equilibrium, the dam relaxes, of course, and the chance is that it fills with water. The interruption just mentioned was of but short duration; the leak was soon overcome, and the dam was emptied at night, and the masonry was resumed the